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LXXII.

SYMPOSIUM ON THE ETHMOID.

THE SURGICAL ANATOMY OF THE ETHMOIDAL LABYRINTH.

HARRIS P. MOSHER, M. D.,

BOSTON.

The subject which is assigned to me, and which begins this symposium, namely the Surgical Anatomy of the Ethmoid, suggests to my mind almost automatically the following topics. The approach to the naso-frontal duct, the removal of the floor of the frontal sinus from the orbit, the presence of a fronto-ethmoidal cell, the relationship of the posterior ethmoidal cells to the sphenoidal sinus and the optic nerve, and, finally, the partial or the complete exenteration of the ethmoidal cells.

The surgical anatomy of the ethmoidal labyrinth means the applied anatomy. Therefore, a detailed description of the anatomy is called for only where it has a surgical application. (Fig. 1.)

If the ethmoidal labyrinth was placed in any other part of the body it would be an insignificant and harmless collection of bony cells. Placed where Nature put it, it has a number of

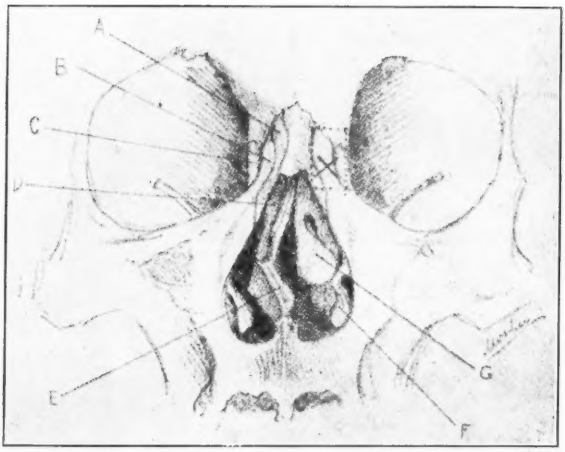


Fig. 1. The relationship of the anterior end of the ethmoidal labyrinth to the middle turbinate, the tip of the ascending process of the superior maxilla, and the lacrimal bone. The position of the labyrinth is shown by the dotted lines; the cross shows the level at which the curette enters the labyrinth. A, nasal bone; B, ascending process of superior maxilla; C, lacrimal bone; D, middle turbinate; E, septum—marked deviation to right; F, inferior turbinate; G, middle turbinate, much enlarged.

major relationships so that the diseases and surgery of the labyrinth often lead to tragedy. It has been said that the ethmoidal operation is the easiest in surgery. So it is to the operator who lacks a surgical conscience. Theoretically, the operation is easy. In practice, however, it has proved to be one of the easiest operations with which to kill a patient. (Fig. 2.)

The lateral mass of the ethmoidal labyrinth is a thin, bony box which is roughly shaped like a pyramid. The wider part, or the base, is posterior, the blunt apex is anterior. The superior face of the box is wider than the inferior.

The ethmoidal labyrinth, or rather the ethmoidal pyramid, occurs in two forms, the typical pyramidal form, and the flat thin form in which the anterior and the posterior diameters are the same and both are much less than normal (Figs. 2-3). One expects in exenterating the ethmoidal cells to have more space

Fig. 2.—Specimens of the ethmoidal labyrinth cut horizontally. The specimens show the variations in the form of the labyrinth. Each labyrinth (about three fourths of the distance back) tends to bulge toward the septum. This inward bulging makes it difficult to see the inner or nasal face of the sphenoidal sinus. In order to do away with this bulging portion of the labyrinth the superior turbinate must be removed flush with the anterior face of the sphenoidal sinus. The third specimen is a narrow labyrinth and the fourth a very wide one.

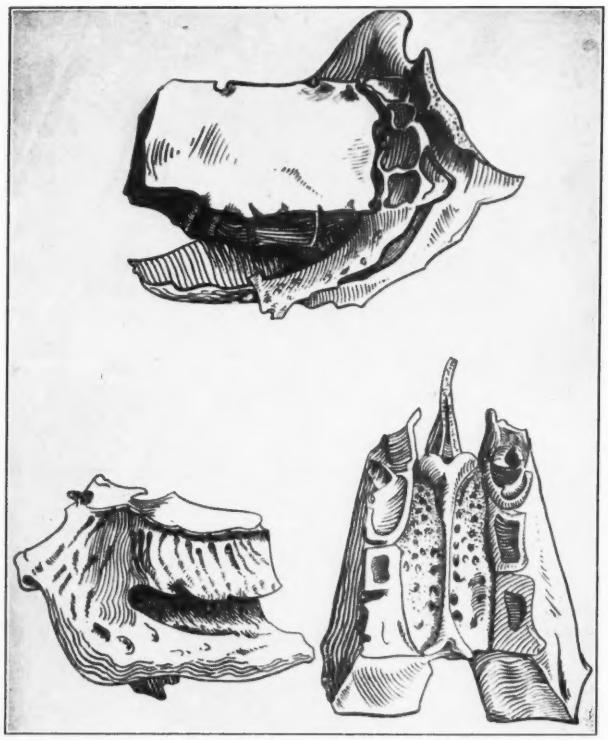


Fig. 3. The Ethmoidal Bone.

posteriorly than anteriorly. This is true in the usual type of pyramidal labyrinth. When, however, the labyrinth is of the thin type, and of the same width throughout, the operating space does not increase. In small thin heads the possibility of this formation must be borne in mind.

The anterior posterior length of the labyrinth is 4 to 5 cm., the vertical height 2½ to 3 cm., the width of the labyrinth posteriorly, that is, the width of the base, is one centimeter and a half or 1.5. The width of the labyrinth anteriorly is one-half centimeter or 5 mm.

If all the partitions within the labyrinth are broken down so that it becomes literally a bony box, it will hold from 8 to 10 cc. (3 drachms).

The lateral mass of the disarticulated ethmoidal bone is incomplete in three places. First, the superior surface along its inner edge has a row of incomplete cells which are made complete by a similar row of half cells lining the ethmoidal notch of the frontal bone. The anterior third of the orbital surface of the lateral mass has a series of uncapped cells which are made complete by the lachrymal bone. The posterior surface, or the base of the labyrinth, has a common wall with the outer half of the front face of the corresponding sphenoidal sinus. Thus in the disarticulated ethmoidal bone, if the lateral mass happens to be complete posteriorly, the outer half of the front face of the sphenoidal sinus of the corresponding side is wanting. Both cannot be complete because they have a common wall.

THE MAJOR RELATIONSHIPS.

The roof of the ethmoidal labyrinth is a continuation of the floor of the anterior fossa of the skull. The relationship of the labyrinth superiorly with the anterior fossa and its contents is the most important. The superior surface is the tragedy surface. It is continuous internally with the cribriform plate and rises in a dome above it some two or three mm. The outer surface of the labyrinth makes the inner wall of the orbit. Two-thirds of this surface are made by the os planum. The anterior third is made by the lachrymal bone. The outer surface of the labyrinth, therefore, is in relationship with the lachrymal bone and the lachrymal sac. That is, the anterior ethmoidal cells are in relation with these two structures and the orbit. The posterior half of the labyrinth contains the posterior ethmoidal cells. These have an extensive relationship with the orbit and at times the most posterior of the ethmoidal cells has a close relationship with the optic nerve. (Fig. 5.) The posterior face of the labyrinth, as has just been said, has a common wall with the front face of the corresponding sphenoidal sinus. This means, of course, that the sphenoidal sinus can be entered at this point from the ethmoidal labyrinth. The perpendicular attachment of the superior turbinate marks the inner limit of the common wall on the front face of the sphe-

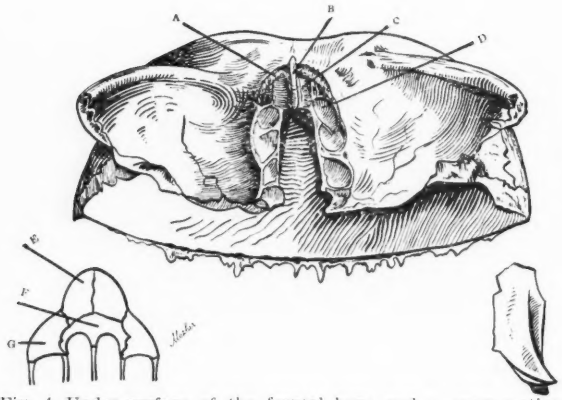


Fig. 4. Under-surface of the frontal bone and a cross-section of the nasal bones.

A. Nasal notch. B. Nasal spine. C. Roof of nasal cavity. D. Nasofrontal duct. E. Nasal bone. F. Nasal notch frontal bone. G. Ascending process of superior maxilla.

Fig. 5. Drawing from a specimen in which the whole ethmoidal labyrinth has been exenterated. The posterior third of the superior turbinate has not been removed. This bulges inward and obscures the inner or intranasal part of the front face of the sphenoidal sinus. It is necessary for correct orientation in operating to remove the superior turbinate flush with the front face of the sinus. (See Fig. No. 6.)

A. Outer or ethmoidal face of the sphenoid. B. Attachment of superior turbinate. C. Inner or nasal surface of face of sphenoid. D. Os planum.

Fig. 6. Diagrammatic drawing of the front face of the sphenoidal sinus. When the exenteration of the ethmoidal labyrinth has been completed and before the sphenoidal sinus is entered the operative field should present this picture. The upper outer posterior angle of the ethmoidal face is the most dangerous area in the operation, i. e., the region of the upper left hand marker A. A, outer or ethmoidal half of frontal face of sphenoid; B, attachment of superior turbinate; C, inner or nasal surface of sphenoid; D, right choana.

noid. The attachment of the superior turbinate roughly divides the front face of the sphenoid into thirds. The outer two-thirds are taken up by the common wall. The inner third, which is the space between the attachment of the turbinate and the nasal septum presents as a free surface in the posterior superior part of the nasal cavity. The lower limit of this space is the upper rim of the choana of the same side. So that the choana and the nasal septum act as surgical guides to this part of the front face of the sphenoid. The superior boundary of the nasal face of the sphenoid is the cribriform plate. The nasal face of the front face of the sphenoid contains in its upper part the ostium of the sphenoidal sinus and in its lower part it is crossed horizontally by the spheno-palatine artery which gains the nasal cavity from the spheno-palatine foramen. (Fig. 6.)

In the normal pyramidal labyrinth of good size, the lower surface of the lateral mass of the sphenoid overhangs the antrum in what is called the ethmoidal overhang. To summarize, the main relationships of the labyrinth are with the brain above, the orbit and the optic nerve on the outside, the outer part of the front face of the sphenoid posteriorly and the antrum below. The cribriform plate is to the inside of the ethmoidal labyrinth and as long as the operator's instrument remains within the labyrinth it is not in danger.

The anterior boundary of the ethmoidal labyrinth is the posterior surface of the ascending process of the superior maxilla. It is the only boundary which is strong. (Fig. 7.) Against this the operator can curet to his heart's content. All the other walls of the labyrinth are thin and must be approached with great care. (Fig. 8.)

The ethmoidal lamella from which the middle turbinate springs, runs outward to the os planum and upward to the roof of the labyrinth, dividing it into two parts, and ends at the anterior ethmoidal foramen. All cells in front of the attachment of the basal lamella of the middle turbinate are called anterior cells, are relatively small and average around 7 or 8. All cells posterior to the attachment of the os planum are classed as posterior. They are larger than the anterior and average 3 or 4. It is not uncommon to have two large cells make up the whole of the posterior half of the labyrinth. The

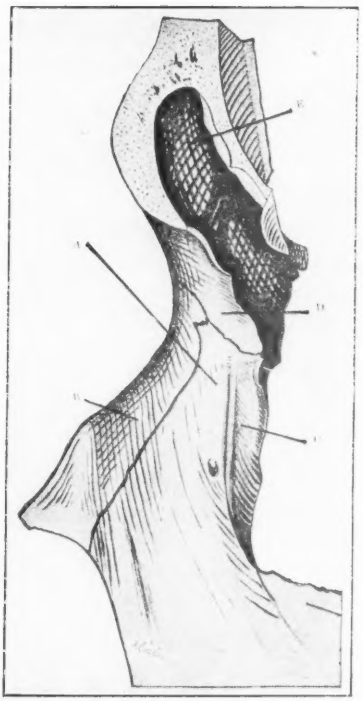


Fig. 7. Drawing from a specimen to show the relation of the internal angular process of the frontal bone to the summit of the ascending process of the superior maxilla.

A. Ascending process of superior maxilla. B. Nasal bone. C. Lacrimal groove. D. Internal angular process of frontal bone. E. Frontal sinus.

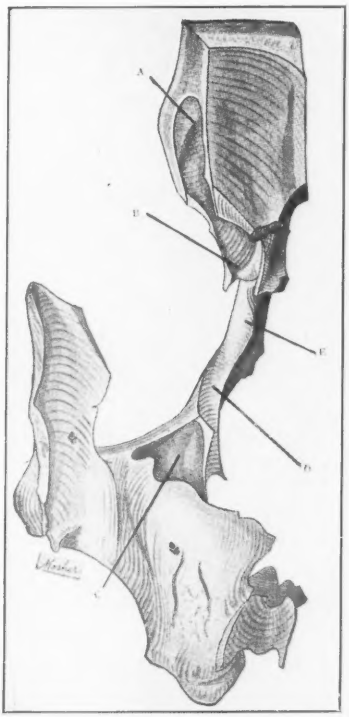


Fig. 8. Drawing from a specimen which shows how the internal angular process of the frontal bone makes the anterior half of the opening of the naso-frontal duct and overlaps like a shingle the posterior surface of the ascending process of the superior maxilla. A probe, carried upward along the posterior surface of the ascending process of the superior maxilla is guided by it into the frontal sinus. If the frontal sinus is approached from the orbit the surest way to find the sinus is to remove the lacrimal bone and then carry a probe upward along the posterior surface of the ascending process of the superior maxilla. In like manner when the frontal sinus is approached from the nose, the operator first turns the anterior cells into one cavity and then in the anterior part of this locates the posterior surface of the ascending process of the superior maxilla and passes a suitably bent probe upward on this as a guide.

A. Frontal sinus. B. Internal angular process of frontal. C. Antrum. D. Lacrimal groove. E. Posterior surface of ascending process of superior maxilla.

smallest total number of ethmoidal cells as given by Schaeffer is 3, the largest 15.

The upper half of the outer wall of the nose is made by the ethmoidal labyrinth; the lower half, by the base of the antrum. From the nose the most accessible part of the labyrinth, surgically, is the agger nasi cell, if present. If not, the ethmoidal bulla.

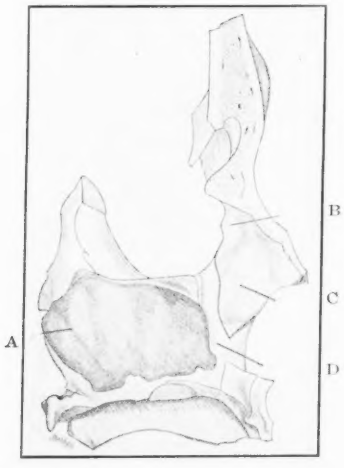


Fig. 9. Drawings from a specimen to show the ascending process of the superior maxilla, the agger nasi, and the lacrimal groove.
A. Antrum. B. Agger nasi. C. Ascending process of superior maxilla. D. Lacrimal groove.

At times the unciform process which is placed in front of the bulla is hypertrophied. When this happens the unciform process would be the most accessible part of the labyrinth.

The lamella of the attachment of the middle turbinate although thin, can be recognized with the curette. The author has met a few instances in the living and a few more on the cadaver in which it was so thick that no force which would be justifiable to use in operating would carry the curette through it. (Fig. 10.)

Fig. 10. Cast from a wet specimen in which the anterior and posterior ethmoidal cells have been exenterated, leaving the attachment of the middle turbinate.

All the turbinates of the nose with the exception of the inferior, or maxillo-facial, spring from the ethmoidal labyrinth. The chief ethmoidal turbinate is the middle. It is equally normal to have one or two ethmoidal turbinates above the middle turbinate. (Figs. 11-12.)

The anterior ethmoidal cells are found in the middle meatus in its upper part clustered around the unciform groove and opening into it. The unciform groove is an embryological slit between the unciform process of the ethmoid and the ethmoidal bulla. It usually ends blindly or in an anterior ethmoidal cell. Only in a small percentage of cases is it continuous with the

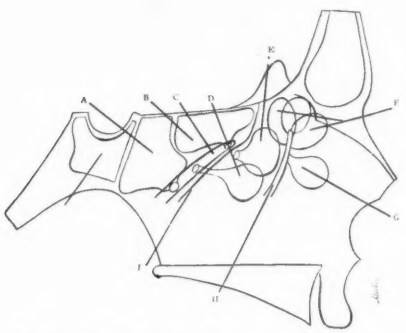


Fig. 11. Diagram of the arrangement of the ethmoidal cells.
A. Posterior ethmoidal cell. B. Posterior ethmoidal cell. C. Third meatus. D. Lower cell of ethmoidal bulla. E. Upper cell of ethmoidal bulla. F. Cells at upper part of unciform groove. G. Agger nasi cell. H. Unciform groove. I. Attachment of middle turbinate. J. Sphenoidal sinus.

naso-frontal duct. When the groove ends blindly or in an ethmoidal cell, the lower opening of the naso-frontal duct is found in the outer wall of the middle meatus in line with the unciform groove and above it, or as Schaeffer says, contiguous with it but not continuous. Anatomically it is not possible to catheterize the naso-frontal duct. As long as gravity holds, however, secretions from the naso-frontal duct readily flow into the unciform groove. Under cover of the flaring lower end

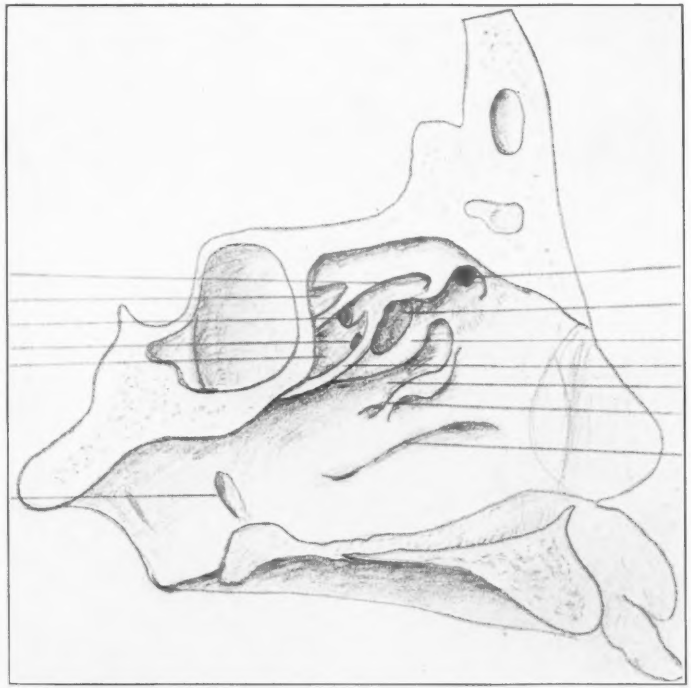


Fig. 12. Student drawing from wet specimen. The unciform groove ends blindly. The opening of the frontal sinus is above the end of the unciform groove and in line with it.

of the unciform process the ostium of the antrum opens into the unciform groove at a right angle. It is difficult, if not impossible, therefore, in the majority of cases, to catheterize the ostium of the antrum. From the surgical standpoint, however, this makes but little difference because it is easy to break into the antrum near the ostium through the membraneous area of the antrum in which the ostium is placed. (Fig. 13.)

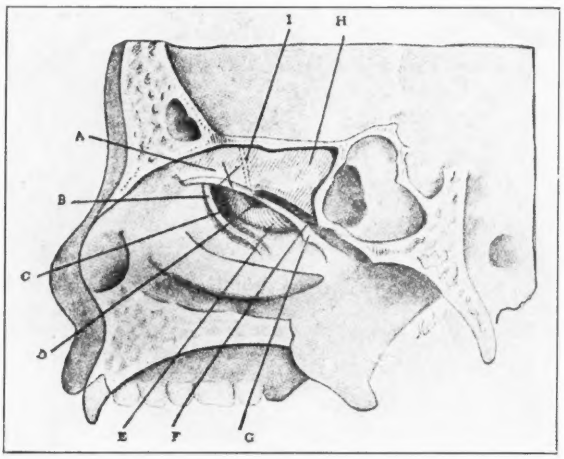


Fig. 13. Drawing to show the anatomy of the nose after the middle turbinate has been removed in the usual manner. It is important to notice that the upper anterior part of the middle turbinate is still in place, and that this portion of the turbinate bridges over the upper part of the unciform groove. Removing the middle turbinate in this manner neither completely uncovers the anterior half of the ethmoidal labyrinth, nor opens it. The cross indicates the point at which the curet is carried into the labyrinth.

A. Upper anterior part of middle turbinate. B. Unciform process. C. Unciform groove. D. Groove of ethmoidal bulla. E. Ethmoidal bulla. F. Third meatus. G. Posterior attachment of middle turbinate. H. Superior turbinate. I. Upper part of attachment of middle turbinate.

It is usual to divide the anterior half of the middle turbinate into an upper part called the superior overhang and a lower part called the inferior overhang. The point of division is a horizontal line drawn forward from the upper end of the third meatus. The anterior part of the middle turbinate bridges across the unciform groove to gain an attachment to the inner

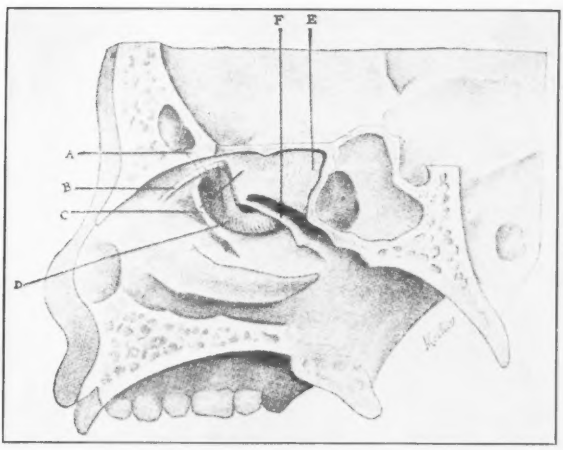


Fig. 14. Drawing from a specimen in which the middle turbinate has been completely removed. By the removal of the upper overhang of the middle turbinate the anterior half of the labyrinth has been fully exposed. Compare this figure with the preceding one, in which the upper overhang of the middle turbinate is still in place. The usual operative procedure deals only with the lower overhang of the middle turbinate. The upper overhang is on a line with the superior turbinate and for practical purposes, continuous with it. A, naso-frontal duct; B, attachment of middle turbinate; C, unciform process; D, ethmoidal bulla; E, superior turbinate; F, attachment of middle turbinate.

surface of the ascending process of the superior maxilla. On the inner surface of the ascending process there is a ridge called the agger nasi. At this point the ethmoidal cell, known as the agger nasi cell, is developed. The lower overhang of the middle turbinate is known in everyday surgical parlance as the tip. (Fig. 14.) It serves to cover the lower part of the bulla and the lower part of the unciform groove. It is below the region of the naso-frontal duct. Secretions from the frontal sinus and the ethmoidal cells drain into the unciform groove, and from here overflow into the anterior part of the nose or make their way down into the antrum. Secretions from the posterior ethmoidal cells flow backward, by way of the third and fourth meatuses, gain the sphenoidal ethmoidal recess between the posterior end of the ethmoidal labyrinth and the

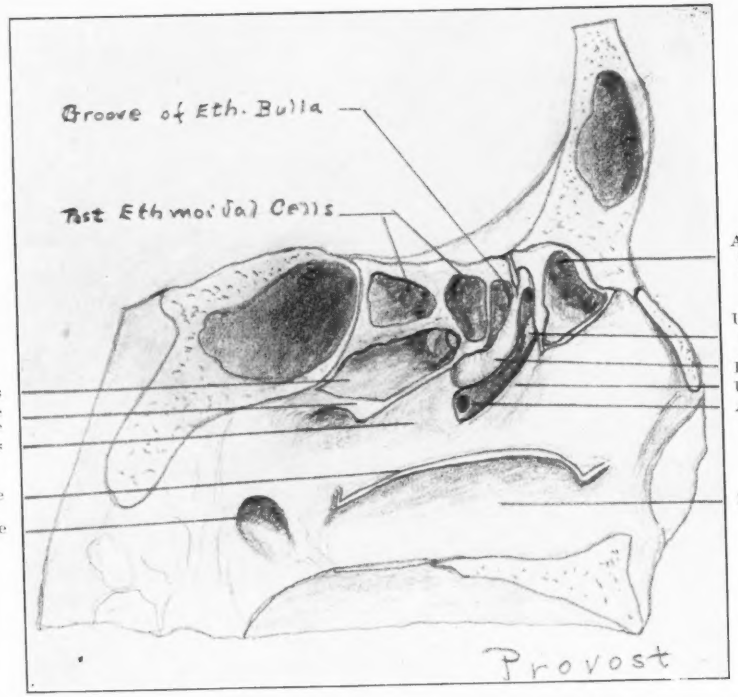


Fig. 15. Student drawing (Provost) from a wet specimen.

front face of the sphenoid and appear on the posterior wall of the pharynx or on the upper border of the corresponding choana. Excessive secretions from either the anterior or the posterior ethmoidal cells disregard purely anatomical channels, fill the whole nasal cavity and appear both at the vestibule of the nose and in the pharynx.

THE BLOOD SUPPLY OF THE LABYRINTH.

The chief blood supply of the labyrinth enters the back door and the door is the spheno-palatine foramen placed in the upper part of the palate bone and bounded above by the body of the sphenoid. Through this is a branch of the internal maxillary artery traversing the zygomatic fossa, and the terminal portion

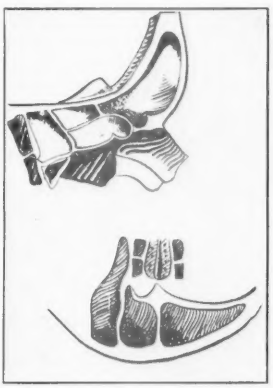


Fig. 16. The upper drawing shows an ethmoidal cell mounding into the frontal sinus (frontal bulla).

The lower drawing shows an ethmoidal cell from the top of the ethmoidal bulla running forward to the orbital run and making an accessory frontal sinus.

of this fossa, the pterygoid palatine fossa, reaches the nasal cavity to divide into two branches, one for the outer wall of the nose which includes the ethmoidal labyrinth, the other by way of the front face of the sphenoid, to supply the septum and on its way there, the sphenoidal sinus. The spheno-palatine artery is the chief blood supply of the nose. Anteriorly through the ethmoidal foramena, branches of the ophthalmic artery by means of the posterior and the anterior ethmoidal foramena, reach the labyrinth.

The veins connect liberally through the cribriform lachrymal bone with the plexus of veins about the lachrymal sac.

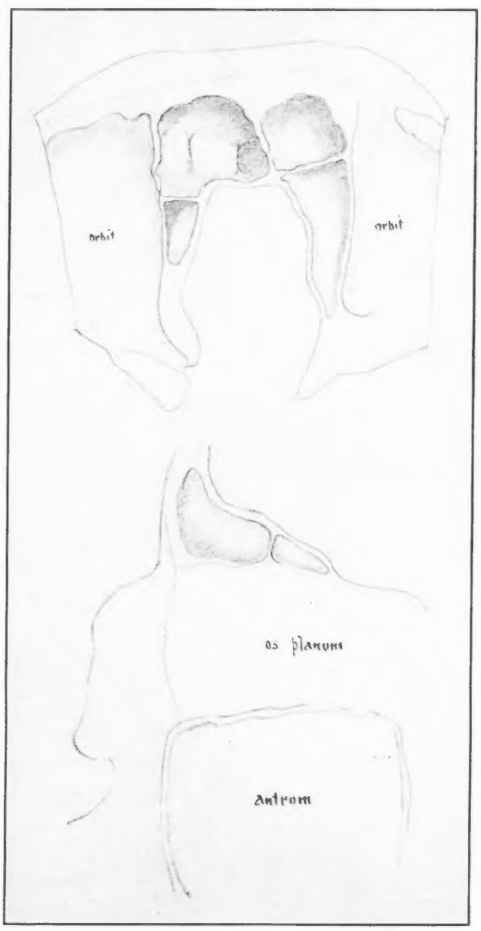


Fig. 17. Student drawing (Wright) from a wet specimen to show a fronto-ethmoidal cell in series with the frontal sinus.

They connect with the main orbital veins and so with the cavernous sinus. There is a connection posteriorly with the pterygoid plexus of veins and so again with the cavernous sinus. Posteriorly also the veins connect with the palatine veins. Through the offshoots of the cavernous sinus and the connection across the bridge of the nose between the angular veins the venous circulation of both orbits are closely associated posteriorly and anteriorly, and the ethmoidal veins connect with the orbital veins.

THE NERVE SUPPLY OF THE LABYRINTH.

The chief nerve supply of the labyrinth also gains its entrance from behind and again through the spheno-palatine foramen. The chief nerve supply comes from Meckel's ganglion placed in the pterygo-palatine fossa, a short distance to the outside of the spheno-palatine foramen. Anteriorly through the anterior palatine foramen the naso-ciliary, a branch of the ophthalmic, gives a supply to the labyrinth.

On the inner surface of the ethmoidal labyrinth in grooves leading to corresponding perforations in the cribiform plate lie the outer branches of the olfactory nerve, the nerve of smell.

The anterior ethmoidal cells which are of surgical importance are first, the agger nasi. This is present in a third of specimens and is found in the extreme anterior superior end of the middle turbinate. Its inner boundary is the flaring upper end of the unciform process. Its outer boundary is the inner surface of the ascending process of the superior maxilla at the point where the ridge called the agger nasi occurs. In series with the agger nasi cell and posterior to it is the lachrymal cell. This is fairly constant. Its outer wall is the lachrymal bone. It has to be entered in the intranasal or the orbital operation on the tear sac. The frontal bulla is another anterior ethmoidal cell of surgical importance. It is a high cell which mounds into the floor of the frontal sinus and is always in relation with some part of the upper opening of the naso-frontal duct. When it is present it makes it easier to enlarge the opening of the naso-frontal duct, working either from the nose or from the frontal sinus. At times this cell reaches the orbital rim to the outside of the frontal sinus and makes an accessory frontal sinus. (Figs. 16-17.)

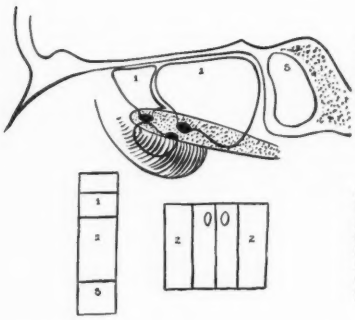
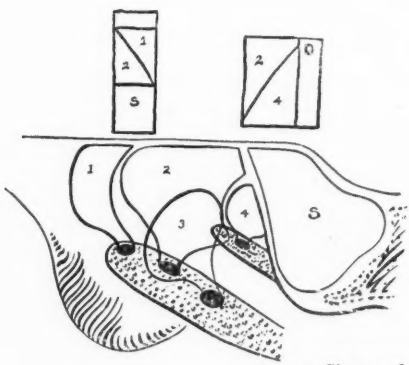


Fig. 18. Drawing from a specimen in which two posterior cells make up the major part of the posterior half of the ethmoidal labyrinth. Very little curetting would be necessary to turn the posterior half of the ethmoidal labyrinth into a single cavity.

The first small drawing below shows the area of the roof of the ethmoidal labyrinth occupied by the summits of cells 1 and 2. The second small drawing shows the area of the front face of the sphenoidal sinus, which has a common wall with the posterior ethmoidal cell.



—Sieur and Jacob

Fig. 19. Drawing from a specimen in which the third and fourth meatus are present. Three ethmoidal cells open into the third meatus, and one into the fourth. The size and the arrangement of the posterior cells is well shown: Cell No. 1 runs outward to the os planum, has its base there and then runs to the roof of the ethmoidal labyrinth. Cell No. 2 is larger, runs outward to the os planum, and then upward to the roof of the labyrinth. It also runs backward and has a common wall with the upper outer half of the front face of the sphenoidal sinus. Cell No. 3 runs outward to the os planum, but does not reach the roof of the labyrinth. Cell No. 4 has a common wall posteriorly with the inner lower half of the front face of the sphenoidal sinus

The small figure above on the right shows the relationship of cells 1 and 2 with the roof of the ethmoidal labyrinth. The small figure on the left shows the relationship of cells 2 and 4 with the front face of the sphenoidal sinus.

The ethmoidal bulla may consist of one ethmoidal cell, but generally contains two. The bulla is the most accessible part of the labyrinth anteriorly and inferiorly. A large bulla can block the lower half of the unciform groove and hinder drainage from the ostium of the antrum. Medially the bulla is covered by the inferior overhang of the middle turbinate. The upper cell of the bulla may grow forward to the rim of the orbit and make an accessory frontal sinus. A more important extension of this cell is upward and outward over the orbit, behind the frontal sinus, and in series with it. Such a cell is called a fronto-ethmoidal cell. When undiscovered and not drained it is one of the most frequent causes of the failure of the radical frontal sinus operation. An X-ray should always be taken in the Water's position in order to show whether or not it is present.

It is not uncommon to have two large cells make the whole posterior part of the labyrinth. Three or four cells are more usual. The most posterior cell is the important one. When the third meatus is the highest meatus this cell springs from the inferior portion of the third meatus and its posterior wall is a common wall with the outer half of the front face of the corresponding sphenoidal sinus. This cell is near the optic nerve —one to five mm. It is common to have the optic nerve mound into the superior outer angle of this cell. The wall of the mound may be paper thin. (Figs. 18-19-21.)

In 62 per cent of cases there is a fourth meatus and in 75 per cent of the cases in which a fourth meatus is present a cell arises from it. This cell generally takes the upper part of the common wall of the front face of the sphenoid, and the cell from the lower part of the third meatus the remaining part. (Fig. 20.)

The most posterior ethmoidal cell frequently is prolonged backward in an extension over the sphenoidal sinus. It may be prolonged backward on the outer wall of the sphenoidal sinus. Such a prolongation of the posterior ethmoidal cell may be so large as to be the surgical sphenoidal sinus of that side, the anatomical sinus being a small affair. This cell is always liable to confuse the operator unless the X-ray, alone or aided by the instillation of lipiodol, picks it out. In cadaver operating

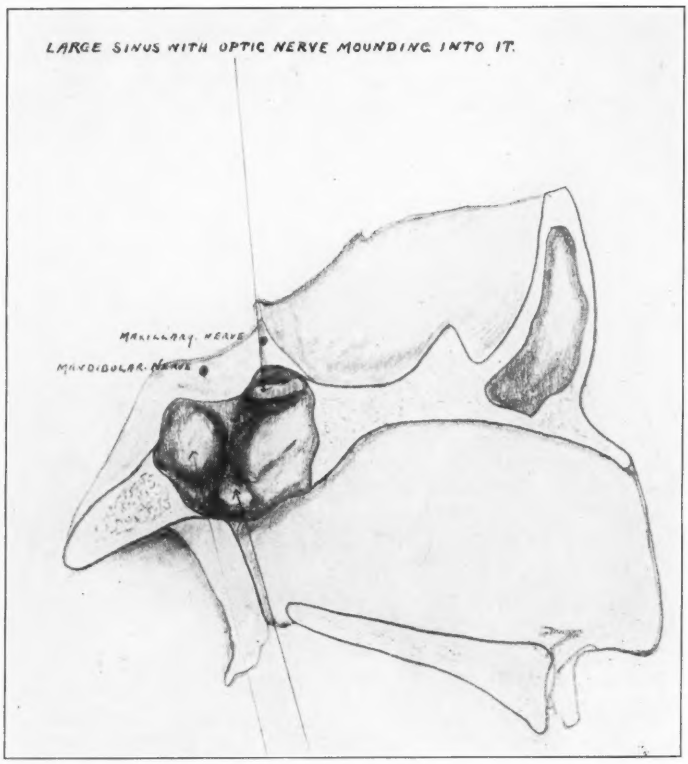


Fig. 20. Student drawing (Wright) to show a large sphenoidal sinus with the optic nerve mounding into it. There are prolongations extending the great wing and into the pterygoid process.

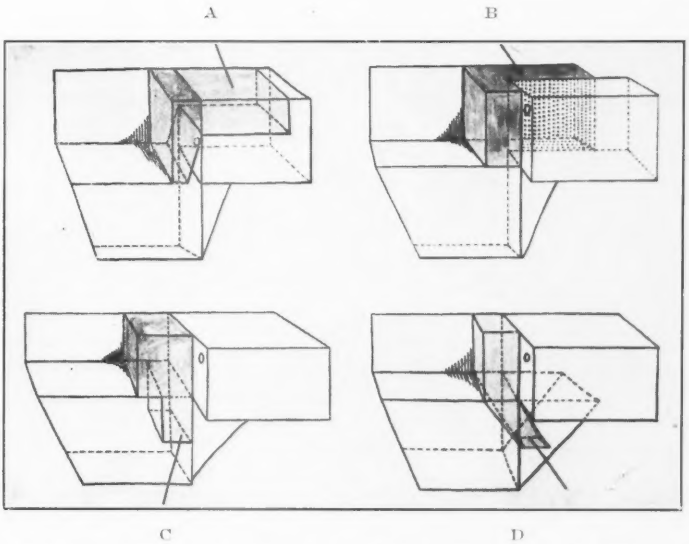


Fig. 21. Diagrammatic drawing to show the anteriors of the most posterior ethmoidal cell. A, extension backward over the sphenoidal sinus; B, extension backward and lateral to the sphenoidal sinus; C, extension downward into antrum; D, extension into the pterygoid process.

this cell is often found unopened when the head is sectioned antero-posteriorly and the operated field examined, and this in spite of repeated warnings on the part of the instructor not to miss it. One is especially liable to miss it, I feel, by the approach to the ethmoid through the antrum.

The posterior ethmoidal cell may mound down into the antrum and even reach the floor of the sinus, making what is called a double antrum. I have found but one specimen of this. (Fig. 22.)

SURGICAL APPROACHES TO THE ETHMOIDAL LABYRINTH.

The surest method of reaching the naso-frontal duct is to make a curette plunge through the agger nasi cell and then curette forward until the posterior surface of the ascending process of the superior maxilla stops the advance of the curette. (Figs. 23-4-5-6-7.) A probe passed into such an

opening and carried up along the posterior surface of the ascending process of the superior maxilla finds the naso-frontal duct in a great majority of cases and enters the frontal sinus. (Figs. 7-8-9.) If there is no agger nasi cells the plunge should be made through the extreme upper anterior end of the middle turbinate. A common mistake in executing this procedure is not to go high enough on the middle turbinate, or far enough back to miss the inner surface of the ascending process. The curette plunge is the writer's favorite method of beginning the intranasal removal of the anterior ethmoid cells. If the curette plunge into the anterior part of the middle turbinate followed by the introduction of the probe does not result in finding the naso-frontal duct the curette is reintroduced and brought forward and the posterior surface of the ascending process of the superior maxilla is curetted free from cells.

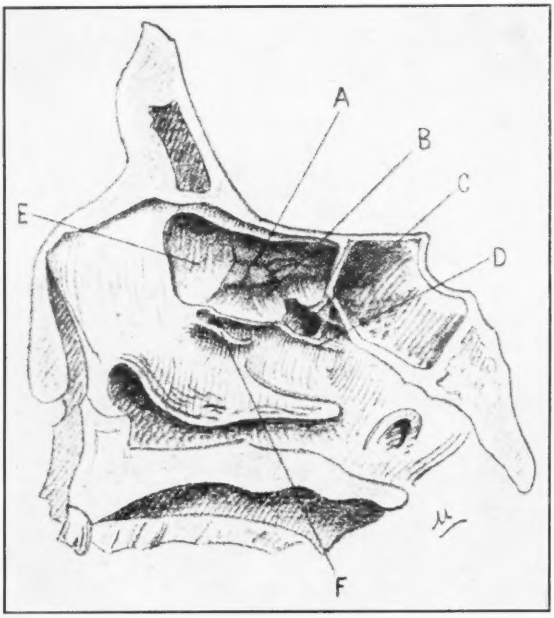


Fig. 22. In this specimen the ethmoidal labyrinth overhangs the antrum markedly and one posterior cell projects downward into it. A, os planum; B, Antral Overhang; C, post-ethmoidal cell overhanging the antrum; D, posterior part of the attachment of the middle turbinate; E, anterior portion of ethmoidal labyrinth; F, unciform process.

LARGE MIDDLE TURBINATE WITH CELLS WITHIN IT.

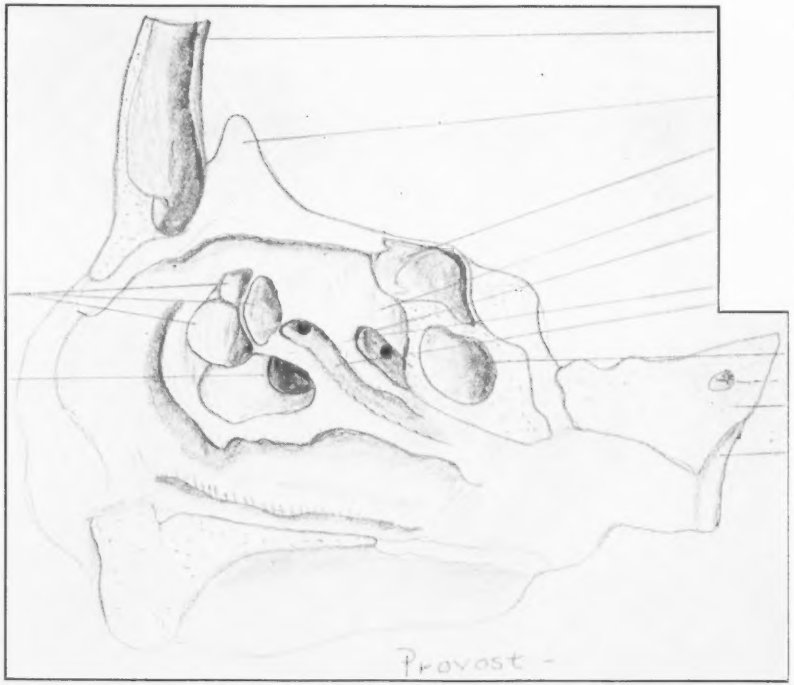


Fig. 23. Student drawing (Provost) from wet specimen.

Another try is then made with the probe. If it fails to pass the curette is reintroduced facing backward and all of the anterior cells are curetted. In a saucer shaped frontal sinus the beginning of the naso-frontal duct is often placed far back. With this in mind the operator, after finishing curetting the anterior ethmoidal cells, introduces the probe to the posterior limit of the operated cavity, carries the point to the roof of the cavity posteriorly and then brings it forward along the outer edge. As has just been said, however, the curette plunge followed by curetting forward to the ascending process is successful in finding the naso-frontal duct in fully 90 per cent of cases. This little procedure which the writer introduced many years ago proved to be a most useful contribution to the applied anatomy of the ethmoidal labyrinth.

THE ORBITAL APPROACH TO THE ANTERIOR ETHMOIDAL CELLS.

Killian taught us to remove a section of the ascending process of the superior maxilla in front of the lachrymal bone, in

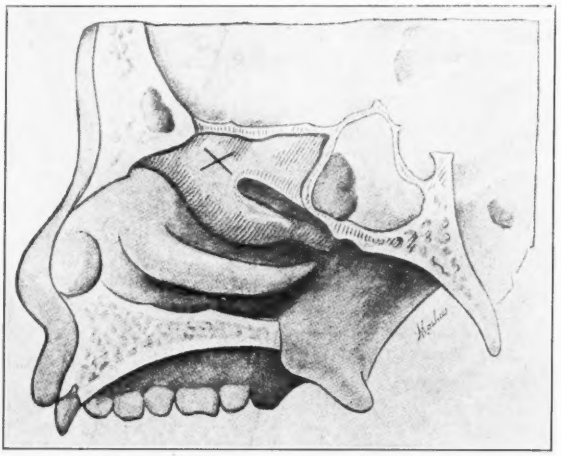


Fig. 24. Drawing showing the middle and superior turbinates. The cross indicates the point at which the curette is carried into the ethmoidal labyrinth. The portion of the middle turbinate below the summit of the third meatus is called in this paper the lower overhang, and the portion above and in front of this point, the upper overhang. The cross is placed on the upper overhang.

order to reach the anterior cells from the front. Many years ago the writer gave up this procedure and entered the labyrinth through the lachrymal bone. This is thin and, of course, easily perforated. Once through the lachrymal bone the operator can work forward and remove as much of the ascending process as he pleases. This saves some ten minutes of time, is simple and more direct.

It was formerly the custom to remove the os planum only as far back as the anterior ethmoidal foramen, that is, to the limit of the anterior cells. The further the operator goes back, however, the easier it is to expose the posterior ethmoidal cells and to make out their extensions. Lynch has called attention to the advantage of the extensive removal of the os planum.

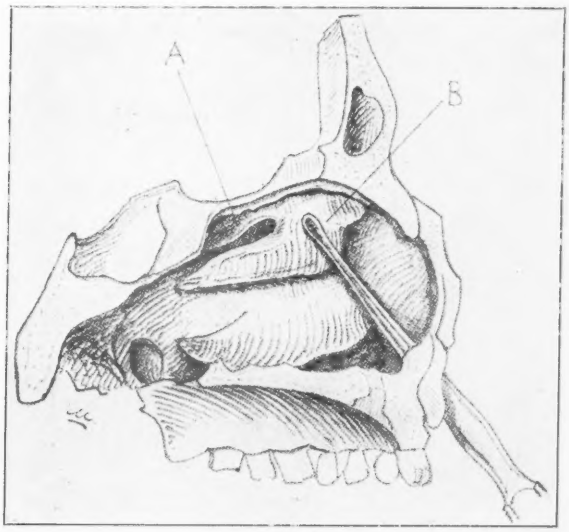


Fig. 25. The writer now begins the ethmoidal operation by removing the inferior overhang of the middle turbinate with scissors and then piercing the superior overhang as in the cut. There are less tags to remove if this is done. The curette is placed against the upper overhang of the middle turbinate for the initial plunge into the labyrinth. A, superior turbinate; B, middle turbinate. If the curette does not enter readily it should be pushed a little higher up and a bit further back.

Of course the removal should not be carried as far as the optic foramen.

THE REMOVAL OF THE FLOOR OF THE FRONTAL SINUS.

In the early days of the radical operation on the frontal sinus, it was customary to remove the floor of the sinus by chiseling from within the sinus downward into the orbit. A surer method of removing the whole of the floor of the sinus is to work within the orbit from below upward and outward. Having gained access to the ethmoidal cells through the lachrymal bone and located the naso-frontal duct, a moderate amount of the os planum is removed. This exposes the inner part of the floor of the frontal sinus where it makes the internal angular process of the frontal bone and articulates with the lachrymal bone and the os planum. The author has found it a very useful surgical conception to consider the floor of the

SPHENOIDAL

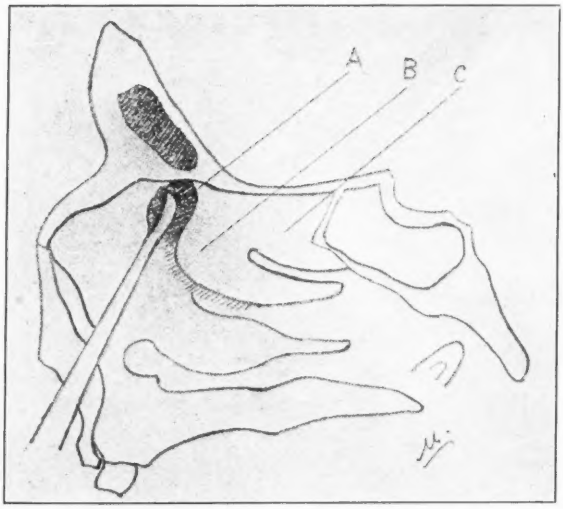


Fig. 26. Position of the curette (face turned forward) in the act of curetting the posterior surface of the ascending process of the superior maxilla. A, ethmoidal labyrinth; B, middle turbinate; C, superior turbinate.

frontal sinus as the upward and outward extension of the os planum. Therefore, after a sufficient amount of the os planum has been removed to allow the probe to ascertain the extent of the floor of the sinus, the operator works upward and outward and backward until the whole of the floor has been taken away. This conception of the floor of the frontal sinus as the upward and outward prolongation of the os planum is simple enough, of course, but the writer was many years in thinking of it. It has proved of great help, however, in operating.

If a fronto-ethmoidal cell is present, the floor of this also is made by the upward outward extension of the os planum and the floor of the cell is removed by working upward and outward after the manner employed in the removal of the floor of the frontal.

At least twenty-five years ago Jansen was accustomed to operate on the ethmoidal labyrinth by way of the canine fossa of the antrum and the membranous area of the base of the antrum. He also approached the sphenoid in the same way.

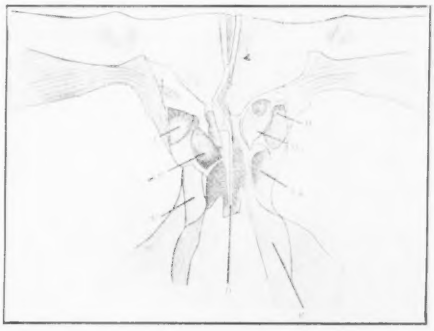


Fig. 27. Drawing to show the relationship of the naso-frontal duct to pockets from the frontal sinus and to ethmoidal cells developed in the ascending process of the superior maxilla.

On the left there is a good sized pocket or prolongation. This springs from the frontal sinus and is below and internal to the duct. There may be a regular cell developed at this place. It is not infrequent to find two such cells. When a prolongation or a cell is present, if the examining probe is carried upward and inward, its point catches in the prolongation. If, however, the point of the probe is directed outwards, the opening of the naso-frontal duct is entered.

A, Naso-frontal duct. B, Pocket of frontal sinus; C, Lacrimal groove; D, Septum; E, Ascending process of superior maxilla; F, Ethmoidal cell; G, Ethmoidal cell; H, Naso-frontal duct.

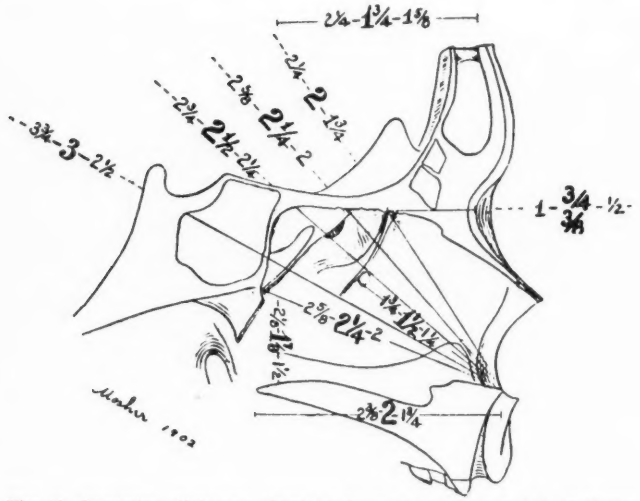


Fig. 28. Operating distances obtained from the measurement of sixty-four half heads. The lachrymal duct is not given on this diagram. The average distance is one inch.

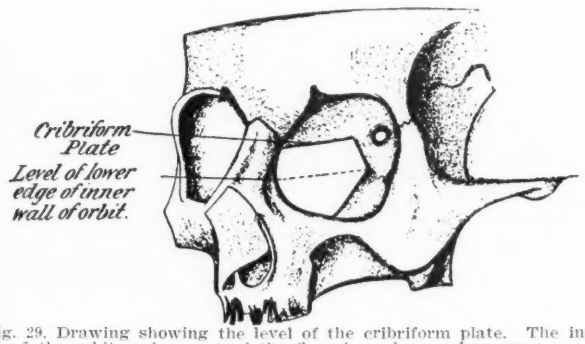


Fig. 29. Drawing showing the level of the cribriform plate. The inner wall of the orbit and a part of the floor have been taken away.

In these days of local anesthesia and adrenalin, the procedure is much easier to carry out because it is less bloody than in the old days. At least one writer has lately advised the revival of the procedure.

I regularly use this procedure in a joint operation on the ethmoid and the antrum, checking up the position of my instrument introduced through the orbital opening into the ethmoid by inspection through the antrum.

Of late years operators on the ethmoidal labyrinth have in increasing numbers successfully employed local instead of general anesthesia. This method of operating has increased the importance of the anatomical location of the nerves and arteries which supply the labyrinth. Fortunately both are very definitely placed. First, the anterior ethmoidal foramen carries from the orbit to the ethmoidal labyrinth the anterior ethmoidal artery and the naso-ciliary nerve. The posterior ethmoidal foramen carries the posterior ethmoidal artery. Through the spheno-palatine foramen from Meckel's ganglion and from the internal maxillary artery come the nerve and blood supply of the labyrinth posteriorly.

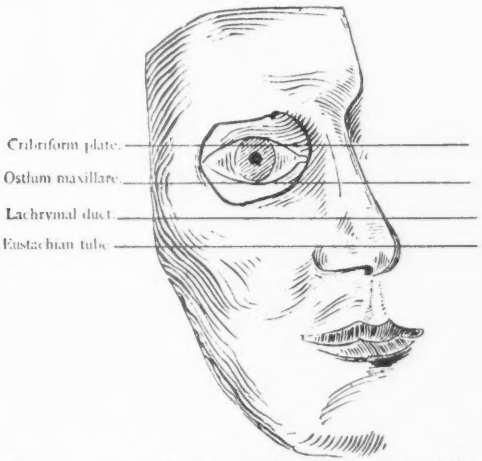


Fig. 30. Drawing to show the horizontal planes of the cribriform plate, the ostium maxillare, the lachrymal duct, and the Eustachian tube.

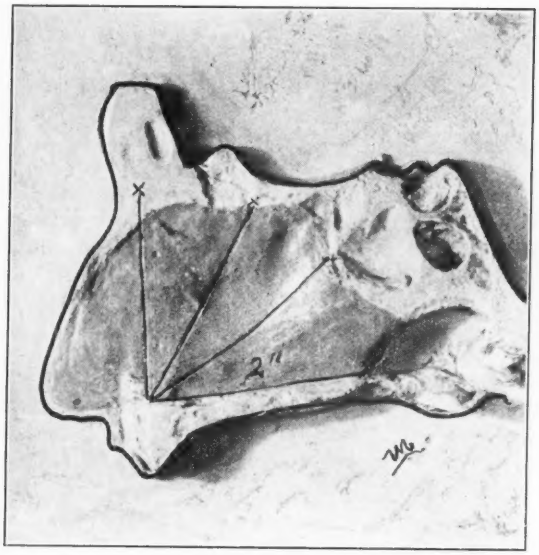


Fig. 31. Cast of ideal septum to show measurements.

Under general anesthesia operators have generally disregarded the ethmoidal arteries. Sewall, however, has brought home to the profession the great advantage of tying the anterior and posterior ethmoidal arteries and in operating on the sphenoid the advantage of tying the sphenopalatine.

NASAL MEASUREMENTS.

A knowledge of fundamental nasal measurements is a great comfort to the operator, especially to the beginner. To make them of the greatest value, each student of nasal anatomy should make at least one set of measurements for himself on a wet specimen. (Figs. 28-29-30.)

Postgraduate students seize with avidity upon a chart of nasal measurements which the writer got out for his own guidance at the beginning of his teaching many years ago. This

chart and one or two others of nasal measurements are included in this paper for reference.

In what might be called the ideal adult septum it will be found in measuring from the base of the anterior nasal spine (see Fig. 31) that the measurement of 2 in. is the measurement to certain very vital and definite points. In other words, the operator should never go beyond 2 in., or 5 cm., in the nose without being on his guard. For instance, the length of the base of the septum is 2 in. The same measurement carries the probe to the middle of the front face of the sphenoid and at the midpoint of the ethmoidal labyrinth, to the cribriform plate. The vertical measurement of the nasal cavity, as will be seen by reference to Fig. 31, is slightly less than 2 in.

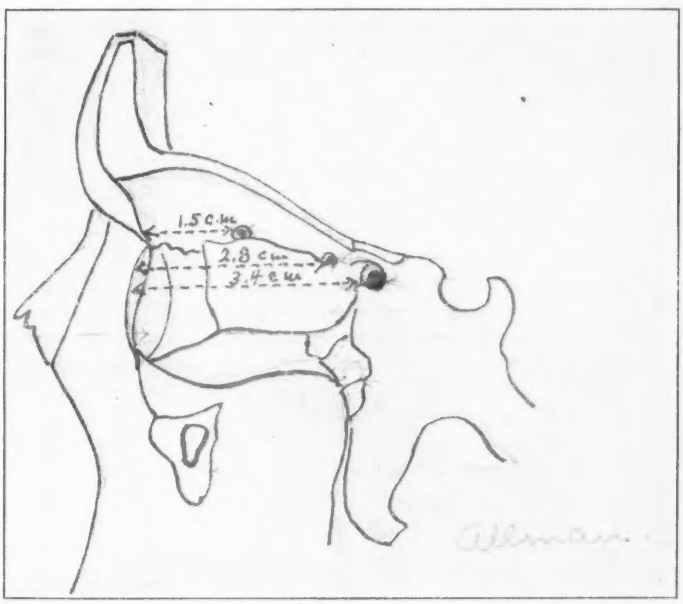


Fig. 32. Student drawing (Allman) from wet specimen to show distances on the inner wall of the orbit.

LXXIII.

PATHOLOGY AND DIAGNOSIS.

By Ross Hall Skillern, M. D.,

Philadelphia.

Ethmoiditis—both the hyperplastic and suppurative varieties—have received so much publicity that to occupy your time with descriptions of the gross pathology of these lesions would be as discourteous as it would be superfluous. We all, of course, know and recognize that the hyperplastic variety may occur without a vestige of discernible suppuration, and the suppurative variety continue for years without the appearance of a polyp, but that these two conditions can and do occur simultaneously no one who has had experience which is worthy of the name can deny. That suppuration may continue for a period of years without the formation of hyperplastic tissue is now so well established that it has become one of the postulates of sinuology. As a matter of fact, suppuration tends to atrophic changes rather than the hypertrophic variety.

There is, however, one point in the gross pathology of the ethmoid that I have found of unfailing significance, and that is the general appearance of the middle turbinate. When this body is healthy it seems to fit in nicely with the underlying structures, the mucosa is smooth and taut, of a pinkish gray, dry, more or less shiny, does not bleed easily, with no traces of any sort of a secretion. Now in my experience, as soon as the ethmoid capsule becomes infected, the middle turbinate begins to reflect the condition almost in direct ratio to the severity of the infection. These changes in the beginning are very slight and at first blush are usually overlooked, unless one especially has them in mind, and even then it often requires the closest scrutiny and frequent comparison with the other side before one is convinced that something is amiss.

These aberrations from normal concern first, the position of the turbinate; second, the size of the turbinate, and third,

the condition of the turbinate mucosa. The position and size of the turbinate are only influenced after the infection has secured a firm hold—therefore, rather late in the disease. The changes in the turbinal mucosa, however, occur comparatively early, which fact alone makes their recognition of vital importance. Ordinarily, on anterior rhinoscopy, the middle turbinate cannot be thoroughly inspected, due to the close proximity of the neighboring structures. There is one portion, however, that can always be brought into view, and that is the lower border in its entire length. Fortunately, this is the very portion that shows these significant changes when infection takes hold, the deviation from the normal being in proportion to the severity of the inflammation.

The usual early change is one of color. The mucosa along the turbinal edge seems to gradually blanch until it assumes a translucent appearance, not unlike a beginning polyposis. This may be so gradual as to give the impression that the process has become stationary, but such is never the case, as the changes are slowly but surely creeping upward along both sides of the turbinate. The longer this continues, the greater the metamorphosis, until finally true polypoid changes are present. Different infections seem to present different pictures. One of the most striking of these is a peculiar mottled appearance on this lower edge and is significant, to my mind, of a deep seated and rather serious infection. In many cases with marked evidences of toxic absorption of particular gravity (in which the heart or kidneys are involved) this appearance of the lower border of the turbinate is present. The body of the ethmoid itself may show little macroscopic change from normal in conjunction with these turbinal changes; however, I have noted that when opened the bleeding is much freer than normal (showing excessive congestion), and a culture by platinum look invariably shows a pure culture of a staphylococcus.

Now a word regarding the microscopic pathology. Here we are first concerned with the differentiation between the hyperplastic and suppurative varieties. When these types are pure, recognition is not difficult, as they show very dissimilar changes, as follows:

HYPERPLASTIC	SUPPURATIVE
Ciliated epithelium remains unchanged except where friction exists as between two polyps.	Epithelium looses cilia early.
Connective tissue meshes dilated.	Connective tissue shows fibrous formation consequently retracted.
Glands hypertrophied (primarily).	Glands atrophied.
Reabsorptive changes in bone (osteoporosis).	New bone formation not infrequent.

When a purely hyperplastic variety becomes infected, with formation of pus, then, of course, the picture presented shows characteristics of both, provided the suppurative process has continued for a sufficient length of time; however, when this occurred the diagnosis has long since ceased to be in doubt. (Slides 1 to 8.)

Diagnosis: From what has been said it will at once be seen that a fairly intimate knowledge of the pathology is essential before one can expect to recognize minute changes sufficient to deduce a reliable diagnosis in the earlier stages of ethmoid infection. The old postulate that in order to arrive at a reliable diagnosis we must find pus and follow it to its source is as obsolete as the dodo, for when pus has formed we know that the general system has reacted against the infecting organism and is probably holding its own. The recognition and diagnosis of this condition would be plain to the merest tyro; what we should do is to recognize the infection before it goes on to the purulent stage, thereby placing ourselves in position to prevent either its spread to neighboring cells or permanent pathologic changes taking place in the ethmoid structures. Now how can this be done? Partly by studying the changes in the position, shape and mucosa of the middle turbinate, and keeping in mind not only those conditions that occur in textbooks but those that we continually meet with in our practices. Let us then consider the textbook conditions with those that we will call actualities, in want of a better term.

TEXTBOOK CONDITIONS.

a. Empyema of an anterior cell or cells.
b. Empyema of a posterior cell or cells.
c. Combined empyema.

d. Hyperplasia.
e. Combined hyperplasia with suppuration.

ACTUALITIES.

a. Generalized infection of mucosa which may occur in a small or large area; rarely empyema of one cell or sharply defined group of cells.

b. General purulent infection resembling atrophic rhinitis.
c. Hyperplasia in various stages.
d. Combined hyperplasia and suppuration.

a. Empyema of Anterior Cell or Cells.—In my experience, despite our previous teachings, this is one of the rarest occurrences per se that we meet with in nasal affections. When a purulent frontal sinusitis exists, of course, an extension downward of the inflammation is all that is necessary to infect the mucosa of any cells emptying into the infundibulum. This combination as an actuality is, however, more apparent than real, for who has ever seen the persistence of suppuration in an infundibular cell after the frontal sinusitis has abated? The one exception to this rule appears to be the ethmoid bulla, for very occasionally one may find it necessary to thoroughly open this cell to evacuate the pent up pus.

b. Empyema of Posterior Cell or Cells.—This form is somewhat commoner than the preceding, but as actual localized abscesses is by far the exception.

c. Combined Empyema.—Excepting the form which will be described later, this is one of the rarest affections that the ethmoid shows.

d. Hyperplasia.—The commonest of ethmoid affections. To enter into a detailed description of polyps and polypoid hypertrophies at this time would be as tiresome as it would be unnecessary. All of us have studied these conditions, both clinically and in the privacy of our studies, so that anything I might bring out here would only be in the nature of a repetition. Let us, however, thoroughly recognize that in contradistinction to the combined empyema, the hyperplastic form represents unquestionably the commonest variety of ethmoid disease that we are called upon to treat. Furthermore, despite the views of many authorities, I simply cannot believe that this

form of affection is, at least primarily, due to microorganismal activity.

e. Combined Hyperplasia with Suppuration. — This form represents an old and very persistent process, being the final stage of a chronic hyperplasia, in which purulent infection had occurred, which in turn had also become chronic. Nowadays we only see these cases in patients who have suffered with hyperplastic ethmoiditis for years and have been operated and reoperated upon many times. As we have now briefly covered the conditions as laid down in textbooks, let us now consider those that we encounter more frequently in our offices.

a. Generalized infection of mucosa which may occur in small or large area; rarely empyema of one cell or sharply defined group of cells. Despite the fact that this form of disease is seldom noted, nevertheless, I believe it to be the commonest type of ethmoid infection capable of causing serious systemic disturbances. In the beginning, it is usually so inconspicuous as to be entirely overlooked and indeed may even be present inside the capsule without disclosing itself by any outward manifestation. As a rule, however, the appearance of the ethmoid base or the middle turbinate will give one a clue, as has been noted under the pathology. That this condition can and may go on to form a collection of pus in one or more cells is perfectly possible and in the earlier days was apparently of ordinary occurrence, but since the sinuses have become common property with the laity, the infection is no longer permitted to progress to this stage, but is usually taken in hand at the onset of the primary symptoms with an anticipated diagnosis of "something the matter with my sinuses."

b. General Purulent Infection Resembling Atrophic Rhinitis.—The older writers were obsessed with the idea that atrophic rhinitis (ozena) under certain circumstances caused purulent sinusitis, and indeed Hajek devoted an entire chapter in his book to this subject. I, of course, accepted this a dictum ex cathedra until, from the repeated dissimilarity of symptoms, it gradually began to occur to me that these cases were different from the usual atrophic cases seen in profusion at that time in our clinics. In the first place, the typical odor was always absent, and secondly, the atrophy seemed to be limited to the inferior turbinals, the ethmoid region being swollen and

hypertrophied. I am now convinced, and have been for a long time, that this affection represents an aberrant type of purulent ethmoiditis which, though comparatively rare, seems to have been noted by everyone who has been interested for any time in sinuology.

c. Hyperplasia in Various Stages.

d. Combined Hyperplasia and Suppuration.

This form represents the result when infection occurs and finds a permanent lodging in an advanced case of the hyperplastic variety. This is caused by the polyps and hypertrophied tissue becoming so widespread as to occlude the upper and middle nasal passages, then infection finding a foothold between these polypoid masses, which gradually spreads and becomes permanent. Confusion is very apt to be brought about when in cases of simple polyposis a purulent infection occurs in an overlying sinus, particularly the frontal. This, however, is of little consequence, as the treatment would be precisely the same, at least in the beginning.

The diagnosis, then, of ethmoid disease, while simple enough on paper, represents, at least in its incipiency, one of the most difficult and painstaking problems that ever confronts the sinuologist.

LXXIV.

CONSERVATIVE TREATMENT OF ETHMOIDITIS.

By Samuel Iglauer, M. D.,

Cincinnati.

The arrangement of the ethmoid cells may be compared to that of a honeycomb. The cell walls are represented by the wax, and the secretion, when present, is represented by the honey. Most of the ethmoid cells drain directly into the nose through small individual ostia, but occasionally there are cells which are connected with the nasal cavity only through a neighboring cell and its ostium. In the presence of infection, this anatomic arrangement leads to faulty drainage and ventilation of the cells with consequent retention of the secretions. The anatomic relations of the ethmoid labyrinth also prevent direct approach and treatment of the cells such as is possible in the antra, sphenoids and frontals. The paranasal cells are probably involved in most cases of acute rhinitis, and undoubtedly the infection has a tendency to spontaneous recovery with the subsidence of the original infection.

PROPHYLAXIS.

The prophylaxis of sinus infection is therefore the prophylaxis of acute upper respiratory infection. In our larger cities, two special factors promote the spread of respiratory disease, namely, crowding of the population and pollution of the atmosphere by dust and smoke. It has been shown, for example, that in Chicago the amount of sunshine has been reduced 12 per cent in the last five years.[1] "The department of health, which has been making observations since early last winter, finds that only half of the sunlight with its curative ultraviolet rays which we find on the tops of buildings reaches the surface of the streets." During those days in which there is little of the ultraviolet light, cases of pneumonia increase as well as the number of deaths.

To the individual who can afford it, winter bathing in artificial sunlight increases his resistance to infection, but for the vast majority of city dwellers, smoke abatement is becoming a necessity for the prevention of respiratory diseases, especially influenza, pneumonia and tuberculosis. Patients who suffer each winter with sinus infection are greatly benefited by spending the sunless months in southern climes, such as Florida, Arizona, New Mexico and California.

Both Dean[2] and Shurley[3] have emphasized the importance of diet as a factor in paranasal disease. To quote Dean, "the second most important thing in the treatment of paranasal disease in infants and young children is diet." Deficiency in vitamin A seems to invite infection. Fenton[4] advises the avoidance of swimming and diving in patients predisposed to sinus infections. The removal of obstructing adenoids in children by restoring the free nasal respiration with its tidal flow, not only prevents but often cures sinus infections. Children should be taught the proper technic of blowing the nose.

Patients who suffer from hay fever or vasomotor rhinitis of allergic origin should be treated for these underlying conditions rather than for the secondary ethmoiditis which may be present in some of these cases.

Syphilis and nasal diphtheria should be excluded before undertaking local treatment.

TREATMENT.

We are called upon to treat ethmoiditis in both the acute, the subacute and the chronic stages. The treatment of acute ethmoiditis is chiefly symptomatic; the objects being to relieve the pain and headache, to restore the patency of the nasal passages; and to favor the discharge of the secretions. For the headache, capsules containing codein and pyramidon are very efficacious. Some patients are relieved by aspirin which also promotes sweating, but which may increase the cerebral congestion. External heat from ordinary lamps or from infrared rays tends to relieve the pain and fullness in the head. Sometimes ice compresses are more satisfactory.

The use of ephedrin preparations, preferably by a spray, tends to relieve the congestion and edema of the mucosa, and

favors ventilation and drainage of the cells. It is a good plan to spray the nose, then wait for a few minutes until the anterior portions of the nasal passages open and then immediately repeat the spraying to open the posterior portions. Suprarenal extract, if employed, should be very dilute (1:10,000). To this cocain may be added to give a 1 per cent solution. The cocain adrenalin spray should be used for a few days only. A recent preparation, "adrephin," a combination of adrenalin and ephedrin, is said to prolong the astringent effect produced by either drug when used alone.

Patients are greatly benefited by the use of the suction pump. A nasal tip is inserted into one nostril, the other is closed with the finger and suction is applied while the patient shuts off the oropharynx by phonating (K) or by swallowing. As I have shown in a previous paper,[5] suction, to be efficacious, must be interrupted repeatedly to allow air to enter the cells and force out the secretion. The negative pressure should be as strong as the patient can tolerate. For home treatment, the rubber suction bulb and glass tip of the Sondermann should be prescribed. It can often be used in children as well as adults. Following suction treatment gentle Politzerization may be employed.

After the very acute stage has subsided, the condition is improved by packing the middle meatus with colloidal silver solutions applied on cotton. I have found hydrosol argentium ("collene") .05 per cent, very satisfactory for this purpose. It may also be used as a spray and does not irritate the mucosa or stain the linen. Argyrol, protargol or silvol tampons may also be employed. This treatment favors osmosis and probably reduces the infection.

If the secretions become thick and tenacious, irrigations with warm isotonic salt solution may be used in adults. In children, only small amounts of fluid can be introduced into the nose without endangering the middle ear, unless the child is held in the prone position with the face down and beyond the end of the table. The development of displacement irrigation by Proetz[6 7] has constituted a distinct advance in both the diagnosis and treatment of sinus disease. By this procedure, it is possible to introduce fluids into otherwise inaccessible ethmoid cells, and to free them of their retained secretions.

In the conservative treatment of subacute and chronic ethmoiditis, as well as in the treatment of unsuccessful postoperative cases, we may employ many of the procedures mentioned above, including suction, irrigation, displacement irrigation and nasal tamponade.

Cases associated with crust formation are benefited by home treatment with an atomizer containing some bland oil to which coryfin and a small quantity of iodin have been added.

It frequently becomes necessary to infract the middle turbinate in order to expose the ethmoid capsule for inspection and treatment. Infraction is usually accomplished with the long bivalve Killian speculum. I have found that the luxation of the middle turbinate is easily accomplished by means of a thin Freer elevator inserted under the turbinate.

Lederer[8] advocates the use of the electrocautery in the treatment of recurrent polyposis without suppuration. He reports a series of more than four hundred cases without any fatalities. Others have refrained from this practice, fearing meningitis as a possible complication of this procedure. The use of radium in the treatment of polypoid ethmoiditis is still in the experimental stage, although reports seem favorable.[9]

The correction of a high deviation of the septum, as well as the removal of hyperplastic mucous membrane and polypi might be considered under the subject of conservative treatment of ethmoid disease, but properly belongs to the next two papers of this symposium which deal with the surgery of ethmoiditis.

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LXXV.

RADICAL TREATMENT OF THE ETHMOID: INTRANASAL.*

By Ralph A. Fenton, M. D.,†

Portland, Ore.

Approach through the narrow threshold of the nostril should impose a certain caution upon the operator, and his indication for operation should be an ethmoiditis limited to accessible intranasal cells. Contraindications of a general nature include disease which may be implanted in or become localized in the operative field, such as tuberculosis and syphilis; disease affecting metabolism, such as diabetes or chronic nephritis, especially when associated with hypertension; severe anemia, especially with relative lymphocytosis; hemophilia, or any prolongation of bleeding or clotting time from nonhereditary causes, may all forbid or at least delay resort to radical intrasanal surgery. Local contraindications include narrowed passageways, whether the small nostril of childhood, or the acquired atresia of healed septal abscess or other severe loss of substance in the vestibule and upper septum. Orbital or intracranial complications of ethmoid suppuration forbid intranasal work, except as a step in adequate external operations. If a coexistent suppurative process in the homolateral frontal or maxillary requires radical external operation, naturally the ethmoid may best be reached at the same time externally.

Allergic hyperplasias affecting the ethmoid are not in our experience suitable for radical surgery, unless secondary stasis of exudates has led to purulent invasion. Such cases repay conservative management.

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Freedom from external scarring and suturing is an obvious advantage, and no disturbance of the orbital contents, save occasional ecchymosis, is likely. Escape from the annoying psychic effect of transient diplopia, such as may readily occur in the external orbital route, is likewise a distinct advantage.

Most important is the fact that where time permits, intranasal surgery may be accomplished in several stages, permitting meanwhile careful study of the ethmoid. Limited areas of the ethmoid may thus be reached, leaving other parts relatively undisturbed. This conservative tendency is gaining acceptance within recent years, in contrast with the very radical intranasal surgery of ten years ago.

Accessibility of the agger nasi and of middle turbinate cells is obviously greater by the intranasal route. (Fig. 1.) The field of vision of the operator is, however, at first rather strictly limited to the anterior halves of the inferior and middle turbinates, the agger nasi and the nasal septum. Anything beyond,

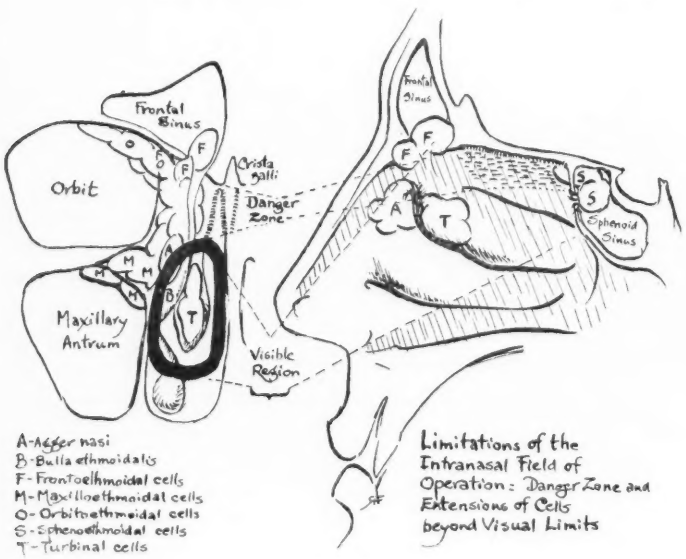

Fig. 1.

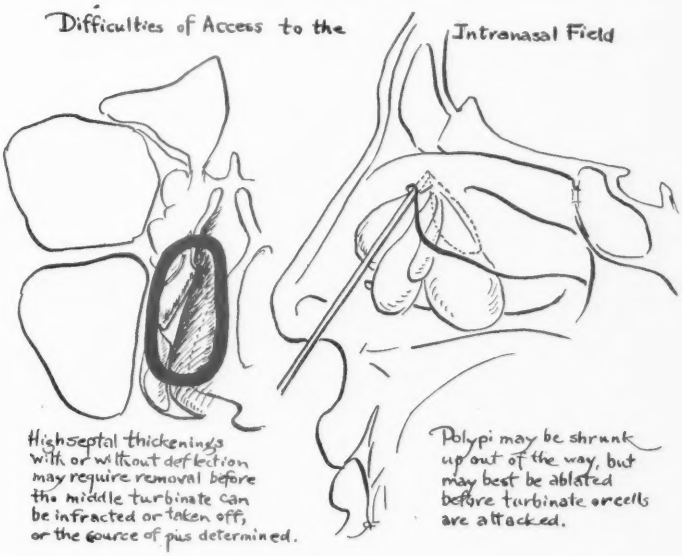
Difficulties of Access to the Intranasal Field
High septal thickenings with or without deflection may require removal before the middle turbinate can be infracted or taken off, or the source of pus determined.
Polypi may be shrunk up out of the way, but may best be ablated before turbinate or cells are attacked.

Fig. 2.

such as the bulla, hiatus and infundibulum, requires extensive shrinkage and often preliminary septal or turbinal work. Extranasal cells in the orbital roof, frontal bullæ, between orbit an antrum, lateral to the sphenoid[1]—are utterly inaccessible to intranasal procedures.

Danger of getting lost in the posterior ethmoid, if the head of the patient be turned up from the horizontal,[2] has been a very real peril in all procedures where the ends of instruments are out of sight of the operator. Very slight anomalies in this complex grouping of dural prolongations, olfactory and visual nerves and blood vessels may lead to complications varying from retrobulbar hemorrhage to optic neuritis or meningitis. Special training based upon dissection, cadaver work and operative experience under the eye of a competent teacher, are needed before intranasal ethmoid work should be essayed. Such is the opinion of Luc,[3] Tilley,[4] Hajek,[5] Mosher,[2] Skillern,[6] Sluder[7] and many other distinguished clinicians.[8 9 10 11 12 13 14] Competence may not be acquired in this field by reading or by study of drawings. Depth perception must be accurate, and

important landmarks must be recognized, in a field likely to be dark, narrow and bloody.

Appropriate preliminary resection must be done if access to the ethmoid is hindered by high septal thickening, with or without deviation. (Fig. 2.) Such resection must often precede the equally necessary and desirable infraction of the middle turbinate. Also occlusive masses of anterior polypi should be removed, as far up as possible, with traction of the snare on their pedicles. Choanal polypi are almost always from the maxillary antrum, but may interfere with access to posterior cells. The latter may, like the antrum, be full of edematous or hyperplastic mucosa but almost never originate pendent polyps. The bulbous-tipped middle turbinate, which contains a cell, must usually be resected.

An effort should be made, by studying stereoscopic radiographs, to determine whether extranasal extensions of the ethmoid are present. Ocular symptoms—transitory dimness of vision, flickering photophores, paracentral scotomata, reduction

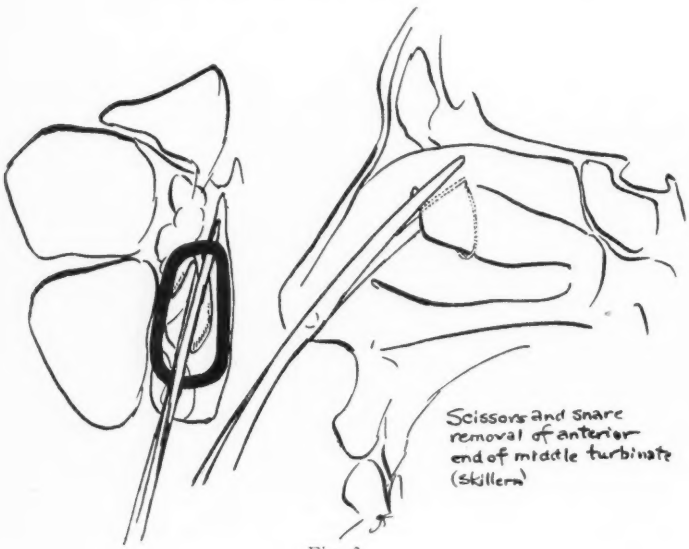

Fig. 3.

of red-green sensitiveness—suggest radiographs in the positions of Rhese or White, to show possible encroachment upon the optic nerve by a posterior ethmoid cell. Lipiodol after ephedrin, by the suction technic of Proetz, has not helped us in anterior cells, though it is very useful occasionally in the posterior cells, as in the sphenoid.

Location of discharge should be accurately decided before the type of operation is selected. The ostia cannot be seen; but (having ruled out frontal and maxillary involvement) long cotton tampons may be packed along under the shrunken middle turbinate, others in the superior meatus back to the sphenoid, and left in place from ten to forty minutes. Inspection will usually show secretion opposite the suspected cells, particularly if some dark silver-protein solution has been used on the cotton tampon for contrast.

The objects of intranasal radical operation, which may best be a succession of relatively conservative procedures, are three: First, to secure aeration, with consequent shrinkage and

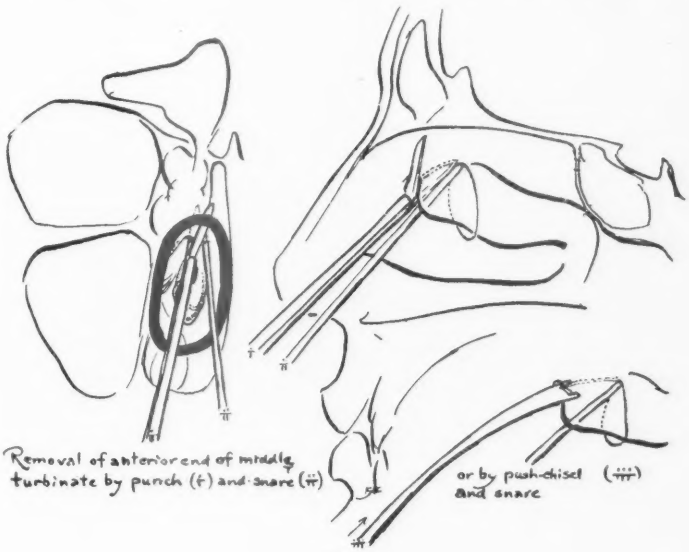

Fig. 4.

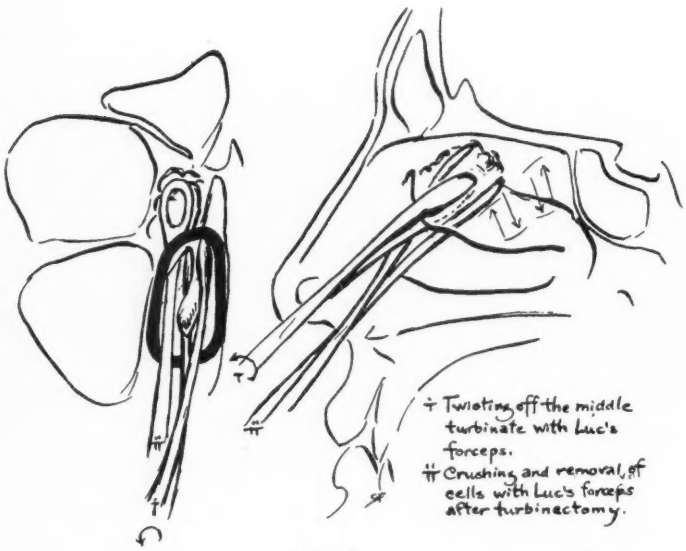
† Twisting off the middle turbinate with Luc's forceps.
‡‡ Crushing and removal of cells with Luc's forceps after turbinectomy.

Fig. 5.

retraction of exposed hyperplastic mucosa; second, to secure drainage, where liquid exudates are actually present; and third, to avoid invasion of unaffected cellular structures during the operation if possible.[6]

Our own preference is for the scopolamin-morphin preparation, with local anesthesia. We prefer this to general anesthesia, which increases hemorrhage during operation and recovery, and subjects the patient to danger of pulmonary involvement from inhaled septic material and blood. Prior to entering the agger region, submucous injection of 1 per cent novocain with a very small amount of adrenalin may be made. For rapid surface action we use 10 per cent cocain with a little 1:1000 adrenalin, but where speed is no object we prefer 5 per cent butyn, also with adrenalin, and have had so far no ill effects from it. These are applied in the usual fashion with two small initial pledgets high up to block the sphenopalatine and anterior ethmoid region; then long cotton tampons, barely moistened by the solution, are placed under the middle tur-

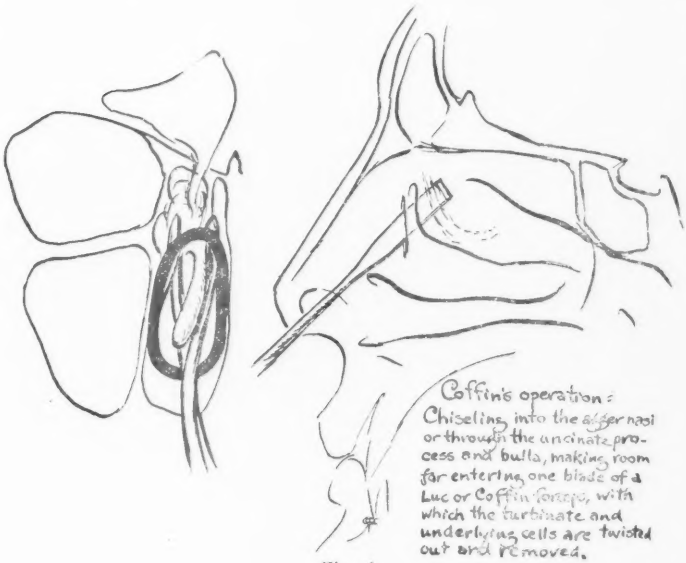
Coffin's operation:
Chiseling into the agger nasi
or through the uncinate pro-
cess and bulla, making room
for entering one blade of a
Luc or Coffin forceps, with
which the turbinate and
underlying cells are twisted
out and removed.

Fig. 6.

binate, about the bulla, and above the middle turbinate from the choanal rim forward about the superior turbinate. We do not like cocain "mud," although many excellent operators use it constantly. Above all, excess solution must not be allowed to run into the pharynx. We have found that the scopolamin-morphin preparation abolishes anxiety and its corollary of fainting or collapse, often ascribed to the local anesthetic. The bother of interruption for clearing the pharynx is avoided by packing a large cotton wad or rolled gauze strip into the choana before extensive procedures are started.

Intranasal ethmoid procedures, then, may be grouped as follows:

Improved methods of access—Septal resection, partial middle turbinectomy, infraction of the middle turbinate, removal of polyps;

Invasion of the anterior cells—Often associated with frontal involvement; operations on the agger nasi, uncinate and bulla (Coffin,[15] Hajek,[5] Halle,[10] Skillern,[6] Mosher[2]);

Invasion of the anterior cells carried back through the posterior cells without removal of the middle turbinate (Pratt[17]);

Invasion of the anterior cells carried back through the posterior cells with more or less complete turbinectomy (Mosher,[2] Tilley,[4] Halle,[16] Skillern,[6] Coffin,[15] Hajek[19]), or from behind forward (Moure-Portmann[20]);

Bloc removal of the ethmoid mass with turbinate attached (Ballenger,[21] Sluder[7]).

We have attempted to visualize simultaneously the picture presented to the operator as he looks up into the shrunken nose toward the middle meatus, with a lateral diagram of each operation. In this way we may see very quickly how much work has to be carried on beyond visual control, in many of these standard procedures.

We find the quick snip of scissors (Fig. 3) preferable to the crunch of forceps (Fig. 4) or the cracking of a push-chisel, for the initial cut of middle turbinectomy. A ratchet pattern pistol-grip snare with stylet, which may be reset, is

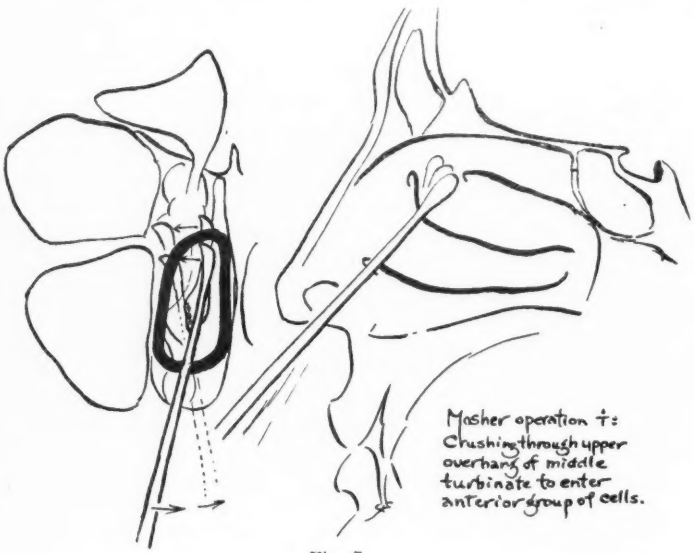

Fig. 7.

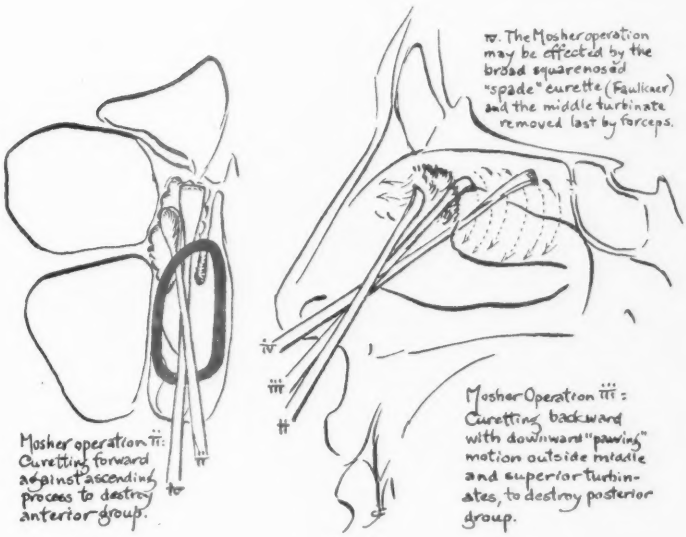
Mosher operation II: Curetting forward against ascending process to destroy anterior group.
IV. The Mosher operation may be effected by the broad squarenosed "spade" curette (Faulkner) and the middle turbinate removed last by forceps.
Mosher Operation III: Curetting backward with downward "pawing" motion outside middle and superior turbinates, to destroy posterior group.

Fig. 8.

better than those which pull a long wire loop around a corner to get stuck in the canula. Twisting off the middle turbinate with Luc's forceps now seems unnecessarily brutal (Fig. 5), though excellent access is thus afforded to the bulla and other cells, which may be smashed up progressively in the broad and relatively safe jaws of these forceps.[3 22]

Coffin[15 28] enters the agger cell and transfixes the uncinate with a flat chisel (Fig. 6), thus making a path outside the bulla for one blade of his forceps. The other blade lies internal to the middle turbinate, and by a twisting closure the anterior mass is broken from place, giving access for such deeper removal as may prove necessary.

The Mosher [2 4 9 10 22 26] operation smashes through the anterior overhang of the middle turbinate (Fig. 7) outward into the anterior group of cells, using his special curette. Thence, with a pawing motion backward and downward, he tears down the remaining septa and the posterior cells as far as the sphenoid, warning meanwhile against backward displacement of

the head. (Fig. 8.) The back part of the middle turbinate has and snare, except at the posterior extremity. Cells in front of the hiatus are curetted forward. The square-ended "spade" curette is safer in most hands than the original Mosher instrument.

Moure's[12 20] operation reverses the Mosher technic (Fig. 9), using a curette almost as large as the Luc forceps, mounted in a double curved handle. The spoon of this curette is sharpened sidewise, but not on the rounded end. This formidable instrument is entered under the back end of the middle turbinate, swept up along the sphenoid wall and forward to the agger nasi, ripping out cellular structures from behind forward as the handle is depressed.

After removal of the anterior end of the middle turbinate, Hajek[5 23] is accustomed to open the bulla with his ethmoid hook. (Fig. 10.) Grünwald's forceps are now used to bite away cells and tags and to open other anterior cells. This hook is also a useful instrument for raking down the superior

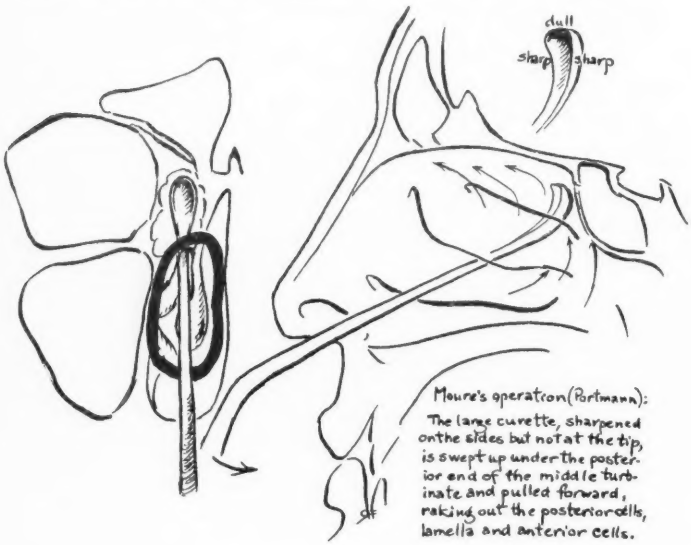
dull
sharp
sharp
Moure's operation (Portmann):
The large curette, sharpened on the sides but not at the tip, is swept up under the posterior end of the middle turbinate and pulled forward, raking out the posterior cells, lamella and anterior cells.

Fig. 9.

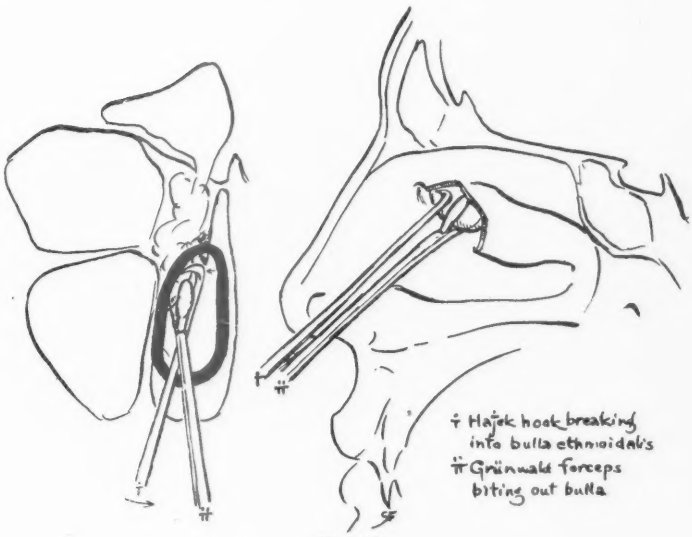

Fig. 10.

turbinate and posterior ethmoid group (Fig. 11) as far back as the sphenoid.[18 19] Its beak should not be long enough to reach through to the orbital wall.

Halle's[16 24 27] technic, primarily designed to give a broad entrance into the frontal (Fig. 12), by rolling down a muco-periosteal flap from the region of the agger nasi and ascending process, gives excellent access also to the anterior ethmoid. Chiseling away the agger nasi and uncinate, Halle infracts the middle turbinate and bites away the ethmoid cells as far back as necessary under the intact turbinate. The flap is lastly turned back over the denuded agger region. Pratt[17] does not remove the agger primarily but curettes forward to reach anterior cells. (Fig. 13.) He preserves the turbinate at all hazards, biting out cellular structures by touch "until solid bone is reached," and removing débris by special large ring curettes and cotton swabs.

The earliest bloc removal (Fig. 14), that of Ballenger,[21] was effected by a large sickle-bladed knife which has a right or left

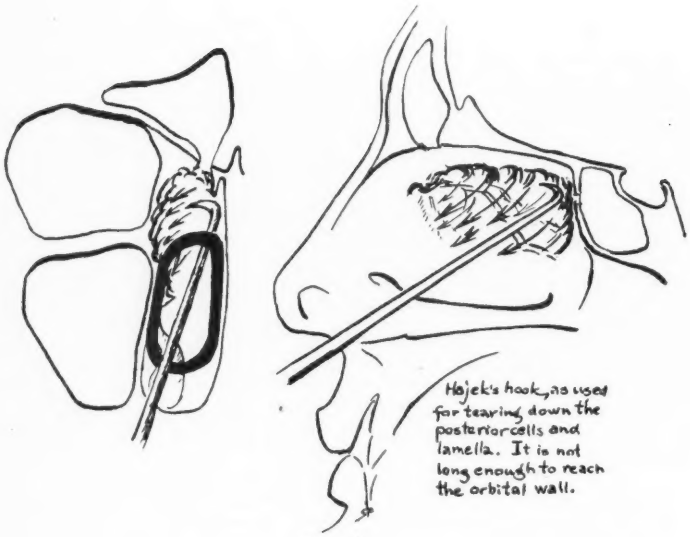

Fig. 11.

handed straight blade at its distal end, set at right angles and long enough to reach from the orbital wall almost to the septum. This powerful instrument is slipped up behind the bulla and under the middle turbinate, and as its handle is depressed the posterior cells, lamella and anterior cells are rocked loose. The entire ethmoid capsule with attached turbinates is thus sliced free and drops down for removal. Carelessness, or unperceived anatomic irregularities have brought about invasion of the dura, orbit or top of the septum during this operation.

Sluder's[7 26] operation required anterior severance under the middle turbinate (Fig. 15) by his short and powerful right-angle knife; he then slid the back of the same knife far along the cribriform plate and turned its square cutting tip outward, dragging it forward to connect with the previous subturbinal cut. The turbinate and its underlying cells, freed if necessary by further lateral cuts through the cell walls, were removed by a snare placed as far back in the incision as possible. Par-

titions thus laid bare were smoothed by knife and forceps. As with Ballenger's operation, this bloc procedure has caused a good deal of trouble at the hands of unskilled operators.

What shall be the procedure of choice for the average operator? Men from various schools, trained by various teachers, will give various answers, of course. To invite discussion, and without any intention of dogmatism, we may suggest the following steps:

In hyperplastic cases:

a. High septal resection. If speed is not essential, wait[6] a while to see if room enough has not been gained;

b. Removal of the anterior end of the middle turbinate; removal of polypi, as completely as possible. Again, wait,[6] if time permits;

c. Remove agger and uncinate by chisel;

d. Break down a bulla with curette and forceps;

e. Curette away affected anterior cells;

f. Break into affected posterior cells with hook, smoothing up with forceps.

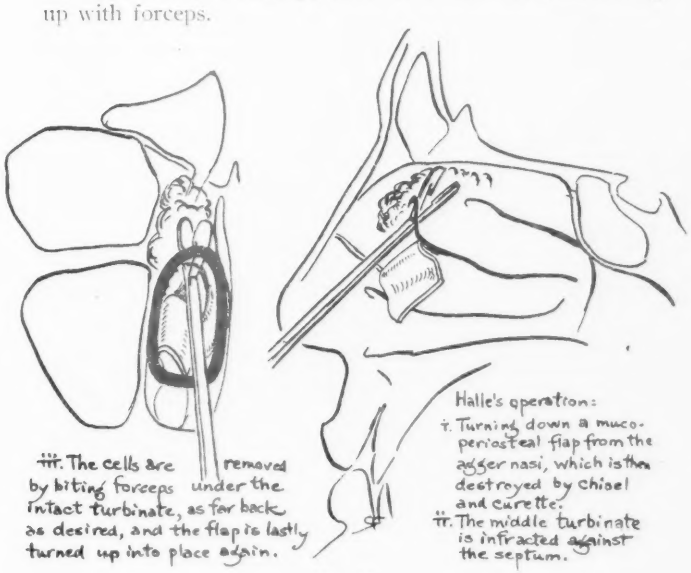
Halle's operation:
i. Turning down a muco-periosteal flap from the agger nasi, which is then destroyed by chisel and curette.
ii. The middle turbinate is infracted against the septum.
iii. The cells are removed by biting forceps under the intact turbinate, as far back as desired, and the flap is lastly turned up into place again.

Fig. 12.

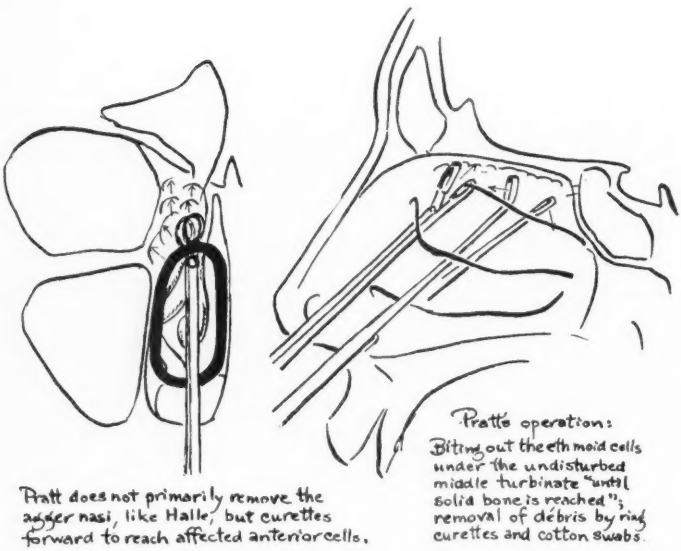
Pratt does not primarily remove the agger nasi, like Halle, but curettes forward to reach affected anterior cells.
Pratt's operation:
Biting out the eth moid cells under the undisturbed middle turbinate "until solid bone is reached"; removal of débris by ring curettes and cotton swabs.

Fig. 13.

The last four steps may be carried out as one operation, but the piecemeal method of delaying the early steps will be found conservative of uninvolved areas and less likely to give rise to secondary infection therein—so-called recurrences—than the extensive one-stage operation.

General suppurative changes involving the entire ethmoid capsule, with or without polypoid degeneration, call for complete removal, and nothing is gained by delay.

In complete suppurative cases, therefore:

a. High septal resection (if needed for access): The septum should be entered from the opposite side, if done simultaneously with the ethmoid;

b. Middle turbinectomy with scissors and snare;

c. Remove uncinate by chisel or destroy bulla by spade curette, depending on the anatomic conformation;

d. Curette and punch away cells to anterior wall of sphenoid, working always back and down, never outward or upward.

Choice of instruments should be limited to those of rather broad rounded outlines (Fig. 16) to avoid inadvertent damage to vital structures. The danger zone at the upper outer angle of the posterior ethmoid must never be forgotten. Mosher's warning that the patient must keep his head level instead of tipping back (withdrawing from the operator) is of vital importance during all intranasal work; otherwise it is easy to lose sight of important landmarks, especially the posterior end of the middle turbinate. Slashing indiscriminately up into the olfactory nerve sheaths may cause fatal damage.

Immediate after-treatment of intranasal ethmoid operations should be limited to hemostasis—for oozing, light cotton tampons with thromboplastin, coagulen, etc., for a few minutes. The wound may be swabbed with 2 per cent mercurochrome, 3 per cent iodin, or compound tincture of benzoin. Packing should never be used.

Subsequent treatment should be of the slightest. Wound exudates should not be disturbed; clots and scabs are best left alone. There should be no swabbing, no spraying, no blowing

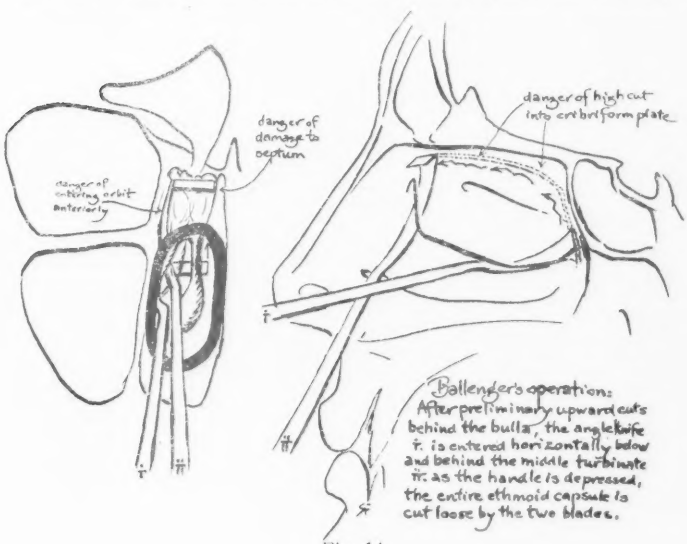
danger of damage to septum
danger of entering orbit anteriorly
danger of high cut into cribriform plate
Ballenger's operation:
After preliminary upward cuts behind the bulla, the angle knife I. is entered horizontally below and behind the middle turbinate II. as the handle is depressed, the entire ethmoid capsule is cut loose by the two blades.

Fig. 14.

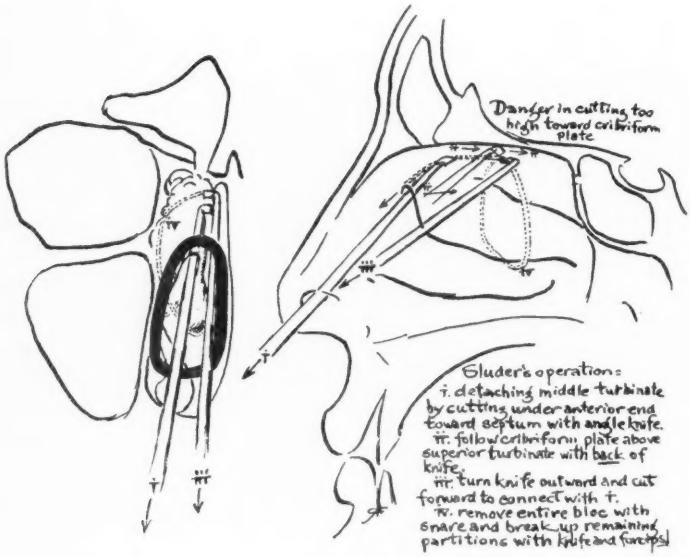
Danger in cutting too high toward cribriform plate
Gluder's operation:
i. detaching middle turbinate by cutting under anterior end toward septum with angle knife.
ii. follow cribriform plate above superior turbinate with back of knife.
iii. turn knife outward and cut forward to connect with i.
iv. remove entire bloc with snare and break up remaining partitions with knife and forceps

Fig. 15.

of the nose, and as little postnasal "hawking" as possible. A few drops of gomenol, ½ per cent, in plain paraffin oil, or a small quantity of boric-lanolin (borofax) ointment, will allay local irritation and facilitate separation of crusts in a few days.

The normal process of healing should not be disturbed by fussy attempts to "clean up the wound." Annoying bleeding and secondary infection, with prolonged convalescence, may readily occur.

Within the strict limitations of its indications, intranasal surgery of the ethmoid has been found highly satisfactory; but excessively radical methods, carried out blindly through the narrow nasal pathway, have not stood the test of matured experience. No better conclusion can be made to this estimate of the present status of these procedures than these words of Herbert Tilley:[30] ". . . It must be stated emphatically that many of the local and general symptoms . . . may

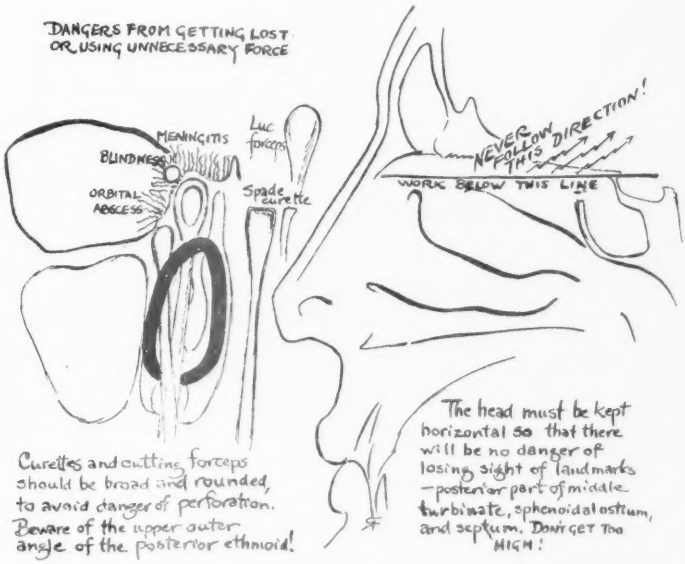
DANGERS FROM GETTING LOST OR USING UNNECESSARY FORCE
MENINGITIS
BLINDNESS
ORBITAL ABSCESS
Luc forceps
Spade curette
NEVER FOLLOW THIS DIRECTION!
WORK BELOW THIS LINE
Curettes and cutting forceps should be broad and rounded, to avoid danger of perforation. Beware of the upper outer angle of the posterior ethmoid!
The head must be kept horizontal so that there will be no danger of losing sight of landmarks — posterior part of middle turbinate, sphenoidal ostium, and septum. Don't get too high!

Fig. 16.

be practically cured by operations which involve little risk in skilled hands, even though the results may not survive the searching criticism of the surgical idealist. Hence it is incumbent on those who deal with these matters—(1) to make an accurate diagnosis of the extent of the lesion; (2) to determine how far the conditions probably threatens the health, happiness and even the life of the patient; and (3) if an operation be decided upon, to bring to it a greater combination of anatomic knowledge, caution and manipulative skill than is demanded in any other form of nasal surgery."

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LXXVI.

SYMPOSIUM ON ETHMOIDAL SINUSITIS: EXTERNAL RADICAL APPROACH.

By R. C. Lynch, M. D.,

New Orleans.

The indications for an external approach to the ethmoid district may be roughly divided into two general classes.

First, the acute manifestations, not only of inflammation and suppuration in this area alone, but more properly because of the extension of this inflammatory process to or towards adjoining important structures, orbit and brain, or on account of some specific accidental injury of such character as to force invasion of this district for the relief or repair of defects or the arrest of complications.

Secondly, as a last resort, to clear up a previously persistent pathology which has resisted all methods of less violent approach or for the eradication of this district as a focus of infection in the presence of a secondary manifestation.

It has always been my experience that the surgery of the first group is not only nearly always emergency in character, but the surgery here in the midst of acute violent septic bacterial invasion is of a type which does that only that will give free vent to pus accumulation, produce sufficient decompression principally on the orbital contents and maintain free drainage, both externally and through the nose until the symptoms of the acute storm have subsided and subsequently repair the drainage in such a way as to prevent a recurrence of another such storm.

What I have had to do under these circumstances was to incise along the rim of the orbit and lateral nasal wall from the supraorbital foramen to the inferior border of the nasal process of the superior maxilla, through the periosteum to the bone, peel back the periosteum along this area, on its lower border only, into the orbital cavity to and beyond its point of rupture from the ethmoid or frontal into the orbit. Open the

frontal at the T suture made by the nasal process of the superior maxilla, nasal and frontal bones, take away the nasal process of the superior maxilla and that portion of the ethmo-orbital wall back to the point of invasion. This not only relieves the orbit of further invasion but is a good decompression for the already inflamed orbital contents, drains the frontal through a large opening, both into the nose and out through the incision, using rubber tubes usually for the purpose, and do not suture the wound.

In three of seven such invasions it was necessary to incise the orbital periosteum from before backward to facilitate drainage of pus from this area, and this, too, in my experience, is the most satisfactory method of draining for orbital abscess of this kind. My slogan is to get in, do that only which is necessary to give free drainage and then get out quickly and fight the constitutional manifestations of the storm by the methods which are familiar to you all.

Six of seven lives, five of six eyes, stand to the credit of the above outline so far; one case died of meningitis, as usual.

The external approach to the ethmoid sphenoid frontal area, because of a long persisting symptom producing chronic pathology, is a far different process. In the first place, there are those who think this the only pathway to approach the problem and all cases of ethmoiditis of a chronic nature must be treated by this route. I do not belong to this school, but feel certain that the external approach will bring about an ideal result, when the methods proposed by Dr. Iglauer and Dr. Fenton fail to accomplish the desired end. Because of anatomic variations, which are many, of pathologic changes, which will not yield to drainage and ventilation, and of the mechanical impossibilities of complete exenteration or evisceration by the intranasal route, there will always be that number or group who must finally submit to the external approach if they expect to be symptom free. Personally, I have never seen a case of chronic suppurative ethmoiditis per se, with no pathology in the adjoining cavities, nor have I seen a chronic hyperplastic ethmoiditis all alone, so that my discussion of this subject must necessarily include the frontal and sphenoid and antrum as well. If either of the above conditions should exist, I am quite sure the methods advocated by Dr. Iglauer first, or Dr.

Fenton next, would cure them, and I would never be called upon to approach the part from an external route.

The problem presents itself, then, after this fashion: Medicine, local and general, including diet, hygiene and climate have failed. Intranasal surgery, no matter by what method or in whose hands, has failed to bring relief of pain, discharge or remove the focus of infection. It is then that the external approach is the only one left, and this must be planned in such a way as to most effectively remove every vestige of pathologic tissue; otherwise this, too, will be a failure. I have never agreed to nor can I see the rationale of thinking that, given a marked pathologic change in the mucous membrane of a sinus sufficient to resist medicinal and intranasal surgical methods, that only a part of this membrane is affected and that operation based on this theory that only the macroscopically diseased membrane should be removed.

Some eyes may be very sharp, but the unaided eye cannot see either microscopic changes in the tissues or its bacterial content. It is more or less common experience, for instance, to submit the tissue thus removed from a sinus to a pathologist, who grinds this tissue and mascerates it, and cultures from this mascerated tissue will many times show a hemolytic streptococcus. Since this has been observed so often as to be a fact, I am convinced that the only fundamental principle to be considered is that which has for its aim the removal of every vestige of pathologic tissue.

Here is neither time nor place to preach conservatism if one is to expect a cure—and likewise I cannot see how conservative modifications of the various radical procedures proposed can be expected to result in a cure, which means that the patient is not only free from pain and discharge but must be free from the focus, not only for present states but in anticipation of what may come if this is not the case. Operative procedures which clear out the ethmoid completely but leave the frontal sinus to drain through a more or less small opening is a mistake. Even the reporter of such a technic admits that the frontal must be sounded for months and admits the necessity of re-entry because of continued symptoms and pathologic manifestations. Also, those who enter the frontal and remove only the neighboring ethmoid cells come to grief for the same

reason. If the antrum or sphenoid are neglected, if diseased, and they most usually are, there will be sadness because of continued symptoms.

It was because of the above experiences, which I observed and waded through myself, that I proposed that technic which has given me the best results in these cases. Since its presentation before the American Laryngological Society, in 1922, and before the Triological, in 1924, I have had what I consider the best evidence that the proposition is correct. Men who have witnessed the operation and have themselves operated by duplicate technic, report to me and in the literature that their results are like mine. I have been trying to satisfy myself what happens to the operative area when healing is complete and there has elapsed sufficient time for the tissue to get set, as it were, to its new order. Looking into these noses, watching the scar and observing the patients, I was convinced that the frontal was completely obliterated as an air cavity and was free from any secretive or absorptive elements, which was the ideal I have striven for. I will show you a group of X-ray plates which seems to me to indicate that at least the frontals are no longer air cavities; that the ethmoid, sphenoid and antrum no longer contain air or secrete fluid. When this result is accomplished, then only is the removal of the pathology complete and the desired end obtained.

My cases number now 148. In this number there are two deaths and no further complications to report that differ from the original, published in the Transactions of the A. L., R. & O. Society for 1924. I am appending a description of the technic I follow, brought up to date. The minor changes are those only of simplification which time and experience have shown to be worth while.

If the antrum is diseased, and it usually is, then it is attacked first, doing a radical Caldwell-Luc operation. If the middle turbinate is still in place, it is removed, and through the antral ethmoid area all ethmoid cells are attacked and cleaned out; also at this time the sphenoid is opened and drained, taking its anterior wall down as near the floor as possible, and its membrane is very carefully removed at this time. I feel certain that the removal of all of the sphenoid lining can be done in a certain number of cases, but this must

be done with the greatest caution and regard for its anatomic relations and boundaries. An antranasal opening into the frontal can be done at the same sitting; this procedure will obviate the necessity for further external approach. If it does not clear up the situation, and it will not in a certain proportion, then the external pansinus operation as proposed is carried out with care for all its details, as follows:

The principle of the attack is fashioned after Knapp's operation; the detail of the technic seems to be that which is ultimately responsible for the proper healing and final cure of the condition. The nasal cavity is prepared as for the nasal plastic in surgery at the persent time—alkalin douches with thorough swabbing with 5 per cent picric acid in alcohol, which will not destroy surface epithelium but has sufficient penetrating power to be of marked antiseptic value; oral hygiene is likewise necessary, and teeth, gums and recesses are covered with the same solution. A postnasal plug on the side operated upon is carefully placed, and the threads are left long enough to facilitate their removal at the completion of the operation.

The skin surface is washed with alcohol and then ether in preference to benzine and solution of picric acid, 5 per cent. in alcohol applied broad and far of the field, extending to the eyelash line on both sides. While the staining of the skin may be objectionable, it has not been found so in my cases and we have noticed less skin infection. The eyebrow is carefully considered in this preparation but is unshaven, and it is apparent that the best cosmetic results are through the unshaven eyebrow. The eye is carefully washed with a bland solution, and the lids are sealed with two Michel clips; these stay in place better and are cleaner and easier to apply and a cushion of gauze is laid over for protection.

One cross cut is made at the upper inner angle of the incision—this is about the location of the T suture and is sufficient for proper suturing after operation. The incision is as for the Killian or Knapp procedure, but does not at first extend outwardly beyond the supraorbital notch until it is found by intrasinus measurement that this is necessary. We proceed gradually through the periosteum, and when this is accomplished all vessels are tied off with the smallest of cat-gut to avoid the possibility of the forceps injuring the eye.

The periosteum is elevated only from the lower half of the incision. If the periosteum is elevated over the frontal plate of the frontal bone or represented by the upper half of the incision it is not likely to reapply itself to the bone again and in consequence there will develop, either immediately or within three months, a periostitis with elevation, and a sequestrum of more or less size will be cast off; this has happened on four or five occasions in my early sinus operations, and I have been able to overcome this disturbance by adhering to this point. It will also protect the patient from the risk of an osteomyelitis gaining its start through this area, especially when the periosteum does not reapply itself quickly, as may happen either from too early blowing the nose or from postoperative edema that follows in some of the cases.

In elevating the periosteum from the lower half of the incision great care must be taken not to buttonhole the orbital periosteum, as this may be followed by disturbance of the orbital balance, but the remotest area of orbit sinus wall must come into view. In elevating the periosteum over the nasal process of the superior maxilla lower lateral edge of the nasal bone in the region of the upper portion of the lacrimal sac, which is carefully dislocated, and in the area of the superior oblique, which is also dislocated, a sharp gouge is found to be the best instrument to use. A long submucous elevator exposes best the lacrimal and lamina papyracea of the ethmoid, in most instances, extending backward to within a few millimeters of the optic foramen. This is necessary to gain entrance to the postethmoid cell group and to give the widest field of approach to the anterior wall of the sphenoid. It must be remembered that the angle formed by the orbitosinus wall or floor of the frontal sinus with its posterior or brain wall must be completely obliterated, and especially is this true at the external angle, for this is the area that most often harbors the infected mucous membrane which causes failure. When the common sinus orbit wall has been carefully removed the mucous membrane of the frontal sinus is carefully curetted away, and again any remaining mucous membrane, degenerated or not, will conduce to failure. With the Coakley curets I have not met so far the sinus which will not permit of a most thorough curettage of the entire cavity. This done, a strip of gauze

soaked in iodin is packed firmly into the cavity to prevent or guard against any infection entering this area from below and it will control bleeding very nicely.

Since Dr. Sewell presented his instruments for the retraction of the orbit and ligature of the ethmoid and sphenopalatine arteries, I have not found it necessary to put in the catgut sutures for retention or retraction of the orbit. I find these retractors more adaptable to the necessities of the work and use them exclusively now. With the removal of the nasal process of the superior maxilla, the lower lateral edge of the nasal bone, the lacrimal and the entire lamina papyracea of the ethmoid, there results a complete evisceration of the entire ethmoid labyrinth, since the middle turbinate has been previously removed and particular search is made for those orbital and sinus extensions of the ethmoid.

The roof cells of the ethmoid next receive our attention, and these can be so comfortably cleaned out by direct vision without the least fear of injury to the cribriform area, though sometimes I lay a stout probe along the roof of the nose through the nostril to act as a safety guide, the end of this probe resting in the sphenoid sinus to act again as a guide when its anterior wall is reached. The postethmoid sphenoid cells standing plainly in view are broken down and every vestige of the mucous membrane is removed in this quarter. Finally the anterior wall of the sphenoid is removed completely; that means to its very limits, and the lining membrane completely eviscerated. This is only possible by such an approach, and even here I do not think can be accomplished in every instance. In the group of cases there is one where this was not done well, and I have had some trouble in controlling a persistent discharge due to this fact. If the nose is cleaned and dried one can get the two angles of view for proper and comfortable orientation. The raw bone surfaces are carefully sponged with tincture of iodin, and this is done as one of the first steps on the frontal plate of the frontal bone. It is not necessary to disturb the nasal spine of the frontal or to open this cancellous area to the wound, because it is a fertile source for subsequent infection and will produce granulation tissue in abundance sufficient to interfere with drainage.

A drainage tube, about ⅛ inch in diameter, with one end cut on a long level, is passed through the vestibule of the nose and lays in what was the area of the beginning infundibulum of the sinus. The iodin gauze is removed from the upper portion of the sinus cavity and the entire cavity is swabbed with iodin. If there has been bleeding from the postethmoid sphenoid region, a strip of iodoform gauze dipped in tincture of benzoin compound is packed loosely to control this area. The frontal area does not bleed. Interrupted sutures of chromic catgut 00 are used to bring the subcutaneous tissues together, but the needle point is not permitted to pass beneath the periosteum of the upper half of the incision, though the suture takes in the periosteum on the lower half of the incision, and they are placed with due regard to the cross cut of the external incision.

The wound edges and neighboring field is carefully cleaned of all blood, using ether for this purpose, and the skin is brought together with metal clips, using only enough tension to secure accurate approximation. No external drainage is necessary. The eye is now uncovered, carefully washed out again and a 20 per cent solution of fresh argyrol is instilled. The eye is left uncovered in the final dressing. I formerly used a quantity of vaselin and a large external dressing. Now I put on a small gauze pad, cut the shape of the incision, leaving the eye exposed. The gauze pad is held in place by small adhesive strips. There is less swelling of the eye tissues, and many times it is opened throughout the convalescence; the wound heals as well and the patient is more comfortable.

The gauze strip is removed from the nose in thirty-six hours and a sterile probe is passed through the rubber tube daily to insure its patulency. The rubber tube is left in place for three days, as a rule, when it is removed and the clips come out, usually on the fifth or sixth day. After the removal of the rubber tube no dilator is used—this differs from the former recommendation to use a dilator. I find there is no necessity for this dilatation, and it is disturbing to the healing process. No washing of the sinus or the nose is permitted, and we feel the less the wound is interfered with after the operation the more rapid and perfect the healing. The discharge, of course, stops at once and does not recur. The healing is complete with

a perfectly cicatrized nose as the result, with no scab formation and no discomfort.

I have now followed this technic 148 times, and my assistants, associates and friends have run this number up greatly. Our experiences agree, and I take it that any technic which will give the same results in other hands than your own is the strongest recommendation that the principles and details are correct—and again I recommend it to you as the best.

LXXVII.

HEREDITY AND HUMAN BIOLOGY.*

By G. H. Parker,

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Cambridge.

It is my intention to discuss with you the sources of human action. To be concrete, how does it happen that I am standing here before you, clothed in a particular way, and forcing my breath in irregular pulses over my vocal cords so as to produce a succession of sound vibrations that pass across the air, reach your ears, and excite in your minds ideas more or less like my own? Such activities illustrate the immense complexities of human relations and call for understanding. I do not mean that in this address I shall solve this general problem, but if we consider the question for a short time, we may come to a clearer understanding of its possibilities and its consequences.

In my opinion there are two springs of human action. The first of these is what we are taught—what I may call our social inheritance. The second is what we bring with us into the world—our organic inheritance. These two sources seem to me to cover all possible human behavior. I am aware that some scholars have declared in favor of innate abilities, but so far as I can see, these always resolve themselves into either a form of social inheritance or of organic inheritance or of some combination of these two. I have never been able to persuade myself that we possess anything more than what we receive from society by learning, and what we bring into the world through our organic nature.

When we examine the way in which we receive these influences, we are immediately confronted with the general process of inheritance, for this seems to lie at the base of both

*An address given before the Academy of Otolaryngology and Ophthalmology at Atlantic City, October 23, 1929.

our social and our organic acquisitions. The term inheritance as used by the biologist is a figure of speech. Inheritance originally is a legal operation. When death occurs and a piece of property is handed from the deceased person to a survivor, we have an example of real inheritance, a legal operation that is made possible by a certain degree of civilization. The biologist sees that a given child possesses some characteristics of the mother and some of the father, and these similarities he attributes to what he calls inheritance. When a child has eyes like those of its mother, we commonly say that it has inherited this feature from the maternal parent, but we know perfectly well that the mother's eyes have not been handed down to the child as a piece of property may be. All that is passed on is some obscure tendency which produces in the child the same kind of eye that the mother possessed. In a similar way habits are passed on, not by immediate transfer, but by a process of imitation, and thus both social and organic inheritances are operations that resemble in a superficial way legal inheritance. Biologists use the term "inheritance," therefore, as a figure of speech, and not to indicate a process such as occurs in the transfer of property.

In organic inheritance we deal with the immense range of physical traits wherein the child resembles the parent. These include color of eye and of hair, complexion, stature and a thousand other obvious external and internal anatomic conditions that make the child like its progenitors. As a rule, these traits are not open to subsequent modification. Physical exercise may change somewhat the proportions of the body, but the color of the eye remains constant for life, and even tricks of the trade on the hair do not involve permanent changes. As a rule, organic inheritance stamps the person with a high degree of permanent individuality.

Social inheritance is illustrated by the innumerable activities that we learn from our early childhood. Perhaps the most striking of these is language. Everyone is aware that the language of a child is the language of its immediate environment and not of its racial source. An English child brought up in France speaks French. I know of a family of American children brought up in China who speak the Chinese language

in a way indistinguishable from a thoroughbred Chinaman. Language is thus learned by example from our environment, as well as are a thousand other such social traits. Among lower creatures this is not necessarily so. If we look upon the sounds of beasts and birds as their natural language, we will find that this language is, as a rule, inborn—that is, organic, in contrast with our language, which is essentially social. The cuckoo in Europe, and the cowbird in America, lay their eggs, as you well know, in the nests of other birds. Their young are hatched in these foreign situations; nevertheless, the young cuckoo and the young cowbird produce notes that are characteristic of their kind and have no relation whatever to the songs of their foster-parents. In the cuckoo and the cowbird language is an organic inheritance, like the color of our eyes, and is not social in its source, as our language is.

Our social inheritances depend upon learning and teaching. Learning is an animal process which reaches down to very primitive creatures. You may be surprised to know that such simple animals as earthworms may learn. An earthworm may be placed in a narrow passageway and made to creep to a point where this passageway turns right and left. Many trials on many earthworms show that these animals will turn right or left in equal numbers of times. If now some irritating agent is placed in one of these passageways so that every time the worm takes the given course it is vigorously stimulated, the worm will in a few weeks learn to turn in the opposite direction and never make a failure in this lesson. Such simple acquisitions are retained by the worm for some considerable time, and remarkable as it may seem, they still persist, even after the animal's head has been cut off and its anterior end regenerated. This shows that such lessons are imbedded in the general nervous system of the worm, rather than in the head of the animal. I am not aware that learning is of much significance below such creatures as worms. Jellyfishes, sea anemones and other simple animals show little or no evidence of this capacity.

Our social inheritance is not only dependent upon our capacity to learn, which, as I have just shown, is shared by many other creatures, but also upon our ability to teach. Teaching, unlike learning, is restricted to only the highest members of

the animal kingdom. Probably birds take some slight steps in teaching their young, and kittens in their play are probably taught by the mother cat, but the so-called "school of the woods" that was once a favorite topic with nature writers probably has no real existence. Teaching is primarily a human characteristic and is our method of substituting a form of play activity for actual experience in life. As ordinarily practiced it never reaches the stage of a full realization. Teaching is always a more or less fictitious affair, yet it prepares for life in a reasonable way and leads to that kind of learning which comes from the world of reality. Human teaching, coupled with our great capacity to learn, lies at the basis of our social inheritance.

Organic inheritance is accomplished through the germinal elements, the egg and the sperm. The remarkable characteristic of this type of inheritance is the immense influence of very small amounts of material. The human egg is a minute sphere measuring about a hundred and eighty-fifth of an inch in diameter. At this stage one hundred and eighty-five persons placed in a row cover just one inch. The amount of substance contained in the egg is, therefore, extremely small, and yet it is this substance that impresses upon the child all those organic traits that the mother transmits. If the real physical basis by which the mother thus transmits to the child is small, that which serves for the father is immensely smaller. The male sperm cell is a minute filament whose length is about one-fourth the diameter of the egg cell, and whose volume has been estimated at approximately one thirty-five thousandth that of the egg. Nevertheless, it is as influential in organic inheritance as the egg, for we know that in organic inheritance children take after their fathers as much as they do after their mothers. When one sees in a boy or a girl the detailed physical traits that have been previously seen in the father, and when one recalls that this inheritance is dependent upon such a minute amount of living substance, it seems almost inconceivable that this is the true explanation of the resemblance. Nevertheless, this has been proved again and again, and we have not the least ground for suspicion that organic inheritance is accomplished by the living substance contained in the egg and the sperm.

In any endeavor to improve man's state, we must take steps to change in a favorable way his real nature. We have seen that the sources of this nature are his social and his organic inheritances. We must, therefore, learn to distinguish in him what traits are dependent upon the social type of transfer, and what upon the organic type. The social type, as represented by the environmental influences of education and the like, was commonly supposed to be the all-important element. If a person had opportunities for education and advancement it was believed that society had given him all that was his due. The organic side of his nature was regarded as wholly secondary, but we are now beginning to perceive that this organic side needs attention, and it is becoming more and more apparent that in dealing with man's betterment we must know with certainty whether this or that peculiarity springs from a social or an organic source. To determine these sources is one of the greatest difficulties in human biology. The problem cannot easily be solved, because we are for the most part such unique creatures. Without attempting to go into the details of this problem, I may say at once that egg cells and sperm cells are so immensely diverse that the particular combination that gives rise to a given individual can scarcely be expected ever to repeat itself. Hence we lack what may be called a standard of reference. Each individual is unique. This standard of reference, could it be established, might enable us to distinguish the social from the organic elements of our nature. For reasons already given, such a standard does not ordinarily exist. In only one peculiar condition (and this seems almost providentially arranged), do we find what may be regarded as a possible standard. This is seen in certain kinds of twinning.

You are familiar with the fact that children are born, not only singly, but in duplicate, triplicate, and in still higher numbers. Some years ago I was interested in ascertaining the extent of these multiple births. So far as I could discover, the maximum number of children at a birth was six. A case of this kind is reported and a monument is raised to the mother in the town of Hamlin in Germany. I know of only one instance of this kind. You will find in American medical records an instance, some fifty years ago in Ohio, of eight children at a birth. This instance, as recorded in several journals,

seemed to me on its face to be clear and indisputable, but when I showed it to a biologic friend of mine, he expressed suspicion as to its correctness, and advised me to write to the county clerk of the region in which it was said to have occurred. Shortly thereafter I received a reply to my letter to the effect that the whole affair was a practical joke, carried out by a person who apparently had some dislike for a family in which twins and triplets were not uncommon. This joker succeeded in putting into a local paper a circumstantial account of eight children born at one time in this family. From this obscure paper the case drifted into medical records and was accepted as true. It should be discarded and, so far as I know, the maximum number of six for human beings retained. I think you will agree with me that this is a sufficient number for any father to receive from his mate. These higher numbers are naturally of very rare occurrence. Twins have been recorded once in about eighty-eight births, and it is to twins particularly that I wish now to refer.

Twins are not always alike—in fact, we can easily distinguish two classes—first, those that are no more alike than are brothers and sisters in the same family. These are commonly called fraternal twins. They may be two boys, two girls, or a boy and a girl, but in any case, they have no more resemblance one to the other than other children in the family born separately. In contrast with these are identical twins, in which the two individuals are always of the same sex and always strikingly alike—so much so that they often cannot be distinguished, even by their near relatives. Such twins occur once in about every four hundred births. In my youth in Philadelphia I knew two girls who were identical twins. It was always their habit, out of politeness, to mention their names when they approached you, for they were indistinguishable to us all. After maturity one became engaged to a young man who suffered the common difficulty of us all and who was often quite uncertain to which girl he was affianced. You may imagine the pranks that these youngsters played upon the young man, who finally succeeded in marrying the girl to whom he believed himself engaged. Literature is full of cases of this kind. The play of Plautus entitled the "Menaechmi" is based upon confusions dependent upon identical twins, and

served as a basis for Shakespeare's "Comedy of Errors," in which the two Dromios and their masters are identical twins. The late Professor H. H. Wilder of Smith College was a very ardent and successful student of these conditions, and pointed out the remarkable degree of similarity between the members of such pairs. He showed that the finger prints and other minute personal details of such twins are strikingly alike, and he recorded a remarkable instance in which identical triplets had been born. These three girls were marvelously similar. Their mother maintained that she knew them apart, but she never allowed the children to lose strings of beads of different colors which were around their necks and which enabled her to determine quickly with which triplet she had to do. It was related that when these girls grew to an age where they were under a governess, two of them slipped away on a lark of their own, and persuaded the third to stay at home and be washed three times by the governess, who supposed that she was bathing one child after the other. This instance shows how strikingly similar in all physical aspects such individuals may be.

The explanation for the difference between fraternal twins and identical twins has gradually been unearthed. I may state it briefly as follows. Fraternal twins are the result of the fertilization of two separate eggs. They resemble the condition in lower animals in which the number of young in a litter indicates the number of eggs fertilized. It so happens that some women discharge more than a single egg at a sexual period, and when this occurs they may produce two or more offspring at a time. The whole situation is a reversion to primitive methods of reproduction, such as characterize many lower animals. Identical twins, on the other hand, are believed to arise from a single egg. The egg is fertilized, and in its growth, instead of producing one individual, it produces two. It is not easy to get direct evidence of this in human beings, but such evidence as there is from the nature of the fetal membranes and such other aspects of human embryology point to the conclusion that the two identical twins have arisen from a single egg. Conclusive evidence on this point has been obtained from one of the lower animals, namely, the armadillo. In this animal, which is found in our Southwest, in Mexico,

and farther south, the rule is to produce four young at a birth. These four are always of the same sex and possess physical traits which relate them as do the traits of identical twins. Any one of such a group of quadruplets resembles more closely the other members of the group than it does either of its parents. The germinal relations have been closely studied in the armadillo, and it is known beyond a doubt that the four young come from a single egg. There is every reason to believe that this is also true of identical twins in man.

From these considerations it is evident that in the case of identical twins we have a real standard for comparison. Identical twins spring from a common germinal source; they are the outcome of a single fertilized egg. From the standpoint of organic inheritance they should be expected to be exact duplicates. They therefore may be looked upon as standards, one for the other, and the differences that we may find in them may reasonably be expected to depend upon the environment —that is, upon social inheritance. It must be kept in mind, however, that many mothers dress their twins in much the same way and in many other respects treat them similarly; hence, under the circumstances, social conditions may impress such pairs in a way to make them strikingly alike. One must, therefore, not confuse similar elements from a social source with similar elements from a germinal one. You will see at once that a true comparison is best made in the case of identical twins that have been separated in their upbringing, and biologists within the last year or so have been especially interested in studying cases of this kind. From what I have said you will understand the great importance of studying identical twins brought up under different environments.

A few years ago Professor Muller of the University of Texas described an interesting case of this kind, and within the present year Professor Newman of the University of Chicago has described three such instances. One of these was of two girls born in London, England, and separated at the age of eighteen months. One continued to live in her native region, while the other was carried across seas and spent much of her life in Canada. After seventeen years of separation they were brought together. The physical similarity

was as striking as could be found in most cases of identicals. One had had greater educational opportunities than the other, and, as might be expected, the intelligence tests gave to the one who had had the better opportunities a higher rating. In temperament the two were strikingly similar, a condition in contrast with the instance described by Professor Muller.

Another example recorded by Professor Newman was that of two young men, born in an Illinois village and separated when only a few months old. They were brought together in a somewhat accidental way some twenty-two years after birth. The two exhibited striking physical similarity, which is especially attested by their finger prints. A pair of these are reproduced on the cover of the "Journal of Heredity" for last April, and they show in a most conclusive way the identity of the twins. Notwithstanding the striking physical resemblance, the psychology of the two young men was markedly different. One was brought up in a large town, the other in a country situation. The town boy showed the effects of a better education, was more reserved, self-contained, experienced, and less friendly than his brother, who lacked a certain degree of dignity, laughed readily and was much more the typical country boy. Here again the social inheritance appeared in a striking way, and in those qualities that we should expect to have had such an origin.

It is perfectly clear, however, that many deep-seated traits of a kind far from what is ordinarily called physical, belong to the germinal group. I have recorded two instances of identical twins, in both of which dementia praecox appeared at about the same time and ran the same course. I also have a record of identical twins, the illegitimate offspring of a vagrant mother, who were brought up separately in families of good repute, and who nevertheless became during school days truants and later vagrants like the mother. By a strange coincidence they were brought together in the same penal institution for vagrancy. It is quite clear from these instances that germinal inheritance not only impresses upon us many of our bodily traits but also touches the inmost springs of our nature, and we must consider ourselves quite as much the product of germinal as of social inheritance. In consequence, the old

view that social opportunity is all that it is needful for the state to provide is being replaced by the belief that it is the duty of the state to concern itself with germinal features as well as with social conditions.

We have had a long experience in adjusting social relations for the betterment of men, but we are complete novices in attempting to control human germinal inheritance. It is difficult to persuade legislators to see the significance and importance of the germinal aspect of population, but I am convinced that they will, sooner or later, and better sooner than later. A few years ago the state of Massachusetts was said to be expending about one-fourth to one-fifth of its income on defective individuals. This income was used in the support of hospitals, asylums and homes for those who were incapable of caring for themselves. Such individuals born into the community are not responsible for their presence there. They are members of the population, and call for reasonable and humane treatment. No state can afford to take drastic measures in relation to them, but their increase may well menace the welfare of any commonwealth. The question that arises is, what is to be done for them. From a social standpoint they should be made as effective members of the community as can be, or, if they are incapable of any useful activity, they should be placed in an environment where as happy a life as can be given them is provided. It is nevertheless true that it would be within the province of any government to reach out its hand and prevent an increase in this type of individual, at least when the defect from which he suffers has an hereditary basis. What steps can be taken by a state in controlling the increase of such individuals is difficult to say, but that some step must be taken is evident.

In experimenting on race betterment it seems quite clear that the place to begin is with the most defective members of society. Those who are state wards and must be cared for by state funds, and whose defects are hereditary, should in some way or other be restrained from reproduction. Such a step may be carried out by segregation, which has been advocated by many public custodians. Males should be kept in one asylum and females in another, and if the separation be

complete and the individuals be not allowed to mix with the population at large, the prevention of offspring ought to be perfect. But it is well known that in institutions of this kind there are many border cases, that pass out into the population and come back again, and in many instances the women of this kind return with child. Such a measure as segregation, while it has its advantages, has this serious disadvantage that it is only an imperfect protection.

A much more radical means of controlling defectives is sterilization. Sterilization is accomplished in the male by a very simple operation of excising small portions of the ducts leading from the testes to the exterior. This operation is not in any sense dangerous, and calls for little more than a slight incision of the skin. A similar operation on the oviducts of the female is more severe, and yet is not attended with serious consequences. Persons who have in this way been rendered incapable of procreation are in no sense restricted in their own activities. Sexual life proceeds with them as with normal individuals, excepting that no reproductive elements, eggs or sperms, are involved. Consequently, while intercourse is possible, offspring never occurs. Sterilization by this process is humane, radical and complete.

When setrilization is considered, it is always easy for one to point out who should be sterilized. We all know the personalities about us who are objectionable, and we can quickly point to stocks that should not reproduce. But sterilization is an operation that should not be allowed to proceed except in proper hands. It is an operation that should be permitted only through a court medically advised. You may be interested to know that legal sterilization has already appeared on the statute books of over twenty states in the Union. It has taken a variety of forms in these various states and has not been very actively practiced. California is perhaps the most forward of those states that have adopted sterilization; it has had a eugenic sterilization law for some twenty years. There are already in California over six thousand cases of legal sterilization. These cases are practically always under state supervision. Some sociologists have urged that sterilization might produce a class of individuals, chiefly women, who

would be misused by unscrupulous men, but this state of affairs does not seem to have materialized in California. The sterilized individuals are under more or less continuous supervision and occupy positions in accordance with their abilities in every day life. The situation is not one to cause alarm. The individuals thus treated lead in most instances what would be called normal lives. The California experiment and that which is beginning in other states will be watched with great interest, for it marks the first step in government control of organic human inheritance, the importance of which we are just beginning to recognize.

LXXVIII.

RECENT ADVANCES IN OTOLARYNGOLOGY: MEDICAL AND SURGICAL TREATMENT.*

By Lee Wallace Dean, M. D.,
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It is impossible to cover all recent advances in the etiology and treatment of things otolaryngologic, nevertheless, there are certain matters more or less new which are assuming great importance in our field. They are influencing our methods by decreasing the indications for operative procedures to the great benefit of our patients.

We are to be congratulated that otolaryngologists today are not strict specialists but are internists with otolaryngologic tendencies. Certainly a knowledge of internal medicine is the foundation of our work.

Those who are especially interested in internal medicine get more useful information from the field of otolaryngology than from that of any of the so-called specialties. Sixty per cent of all human ills are located above the diaphragm.

A thing that we hear much about today is the allergic nose. A knowledge of allergy has saved many patients unnecessary operations and has been responsible for excellent results.

Piness and Miller[1] report that of 834 allergic patients 413, or 49 per cent, had had nasal operations without benefit. The 413 patients had 704 operations; one patient had eighteen nasal operations.

Lintz[2] reports 300 allergic patients, 56 of whom, or 18.7 per cent, had operations on the nose or throat.

Perhaps all of these operations were justified; I do not know. I do know, however, that I have seen cases of sinus disease in children and adults where operations have been strongly advised by laryngologists and where a perfect result has been secured by the exclusion of an allergen from the diet or by preventing contact with exciting substances.

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*Read before the American Academy of Ophthalmology and Otolaryngology at Atlantic City, October 21-25, 1929.

I have in mind a child with macroscopic pus running from the nose: sinus disease it was called. Immediate operation was advised. Microscopic examination of the so-called pus did not reveal a single polynuclear cell. Almost all of the cells were eosinophils. The allergist withheld milk from the diet with a perfect control of the nasal condition.

Contact with the allergen produces acute sinusitis. One must constantly be on the watch for this allergic state. An almost infinitesimal amount of the allergen may produce a reaction. In the cocoon of the silkworm is a protein substance of no value in silk cloth. Every effort is made by washing to get rid of this substance in the cloth. Nevertheless, persons sensitive to this allergen will give a reaction in the presence of silk.

Allergens in the diet we know cause reactions. An allergen in the diet to affect the nasal mucosa must do so through the circulation.

I do not know if proteoses and peptones are absorbed from the intestinal tract. If not, some of the unstable complex substances which are formed during the hydrolysis of the proteins and their conversion into amines must be absorbed if we are to have an allergic reaction.

Operations on the nose and throat of these cases often benefit them temporarily—why, I do not know. Succeeding operations are less beneficial and eventually the patient is not improved.

There is no objection to operating an allergic patient if the patient has been carefully studied and if the indications for the operation are definite. As to whether there is such a thing as bacterial allergy, I do not know. I do know that allergic patients are at times relieved by the control of chronic suppurative sinusitis or by the removal of nasal polyps, or both.

The point that I wish to emphasize is the need of knowing the allergic state of your patient before operating.

Eyermann[3] includes as allergens in nasal allergy foods, pollens, animal emanations, dusts and certain drugs.

Allergy is characterized by an edema of the membrane of the part involved, with an increase in the eosinophils in the discharge.

Hansel showed that the changes in the nose and sinuses were quite comparable to those of the lungs.

The absence of eosinophils in the nasal or sinus discharge does not exclude allergy. The significance of eosinophilia I do not know.

Coates has shown the abundance of eosinophils in the mucosa in asthmatics with rhinologic disturbances; in his cases they were uniformly present in large numbers. In chronic asthmatics there was an increase of eosinophils in the blood.

Baum reports eosinophilia in parasitic conditions and is of the opinion it is not specific for asthma.

Mosher has observed asthma without eosinophilia. These observations confirm our findings that the absence of eosinophilia does not exclude allergy.

Dr. Alexander is working on a definite plan for examination of discharges that will give definite percentages of eosinophils. This should help very much. Certainly 5 per cent eosinophils in a nasal discharge is not significant of allergy.

Proetz has shown that sinuses do not fill well in allergy. In quiescent periods they may fill perfectly and the membrane of the sinus be of normal thickness. During and after an allergic attack the sinus lining may be swollen. Dr. Proetz and I have seen this happen.

Hansel's study of the tissues in allergy is very illuminating. The main finding, as I view it, is the abundance of eosinophils in allergic tissues as compared with the nonallergic. I would advise a study of his report.[4]

Pus and fever in an allergic patient suggest something besides allergy. The allergic edema interferes with ciliary action in the sinuses, which predisposes to stagnation and infection.

The allergic nose becomes very sensitive to drafts, weather changes, etc. It does often resemble infection. The woman who picks her ducks on rainy days because the weather is not fit to work out of doors may have an allergic thing and not an infection.

Allergy is not confined in its action to the nose and throat. Rarely it hits the eighth nerve and its endorgan, causing what seems to be an angioneurotic edema of the nerve. At any rate, the patient has a sudden loss of function of the eighth nerve.

The lesion disappears as suddenly as it comes. It is usually accompanied by angioneurotic edema in other parts of the body.

In every case of sinus disease we must think not only of the possibility of an allergic state but of nutritional disorders. Deficient diet plays a most important rôle in the production of sinus disease. The work of Daniels and Shurly is revolutionizing our conception of what sinus disease is. It is more important to know what prepares the tissue for infection than to know the infecting organism. If it were not for allergic states, nutritional disturbances and endocrine disorders we would not have many cases of sinus disease.

The control rat in the same cage and exposed to the same organisms as the rat on a deficient diet does not develop sinus disease.

Dr. Daniels showed that every white rat fed on a diet deficient in vitamin A developed a sinus suppuration.

In speaking of the pathology of sinus infection we mention often hyperplasia of the epithelial cells and metaplasia of the cells.

Wolbach of Harvard and Smith of Yale have shown that with a diet deficient in vitamin A we get hyperplasia of epithelial cells and a metaplasia of these cells in different parts of the body: at the base of the tongue; in the submaxillary gland; in the pelvis of the kidney; and what is to me of greatest significance, these changes precede the infection. There is room, however, for an enormous amount of work before our conception of the etiology of sinus disease is complete.

To me a deficient diet does not cause infection of the sinuses: it produces changes in the epithelial layer of the sinus membrane which perhaps leads to stagnation in the sinus and consequent infection.

Allergy, I think, often produces an infection of the sinuses in the same way. Certainly in nephrosis the edema of the sinus lining and stagnation causes the infection.

This is quite a different opinion from the one I held a few years back.

In children one is dealing with chronic infections of the sinuses of not many years' standing, and the etiologic factors should not be difficult to discover. They are however, numerous and complicated. One must consider poor hygiene, in-

cluding improper clothing and ventilation; allergy; metabolic disturbances, especially lack of sunlight and dampness; swimming; endocrine disturbances; nephrosis; diseased tonsils and adenoids; nasal blockage and infection, especially in contagious diseases.

The ease with which infections invade the mucous membrane is dependent on one or more of the predisposing factors. In the absence of allergy, it is evident that not only does a perfectly healthy, robust child resist infection better than a poorly nourished child, but infection, when present, does not have the same clinical significance in the two types of child. In the robust child it may be of little importance and can be readily eradicated, while in the poorly nourished child it may exert a deleterious influence and may be difficult to cure.

The importance of deficient diet in the production of chronic nasal sinus disease cannot be overestimated.

Diet must be considered in every case of sinus disease. Many a so-called nasal headache is relieved by an increase of the vitamin A in the diet.

The first thing to be kept in mind in connection with treatment of chronic nasal sinus infection in children is that if the best result is to be secured the proper laryngologic treatment must accompany the dietary. Only in incipient nasal and ear infections the desired result may be secured by dietetic and hygienic treatment alone.

Whenever there is interference with the drainage of the sinuses or ears, it is questionable as to the amount of good that will be secured by the administration of vitamins. Deficient drainage should always be corrected.

In adults as well as children a diet rich in vitamin A is indicated. Adults do not respond so readily to changes in diet as children. Marriott[5] suggests that this is due to a fair amount of vitamin A being stored in the body in glandular fats. He remarks, however, that ultimately, whether young or old, individuals deprived of vitamin A develop loss of strength and resistance to infection, especially tuberculosis and sinus infections.

Dr. Daniels demonstrated that in the early stages of sinus infection in the rat, produced by deficient diet, the sinusitis could be corrected by suitable diet; that when once established,

diet would not bring about a cure. This confirmed the observations just mentioned.

Following this observation, we established a normal infant ward to study the growing infant. Dr. Daniels was placed in charge. Newborn infants were placed in the ward and remained there until they were two years old. We must remember that not only did these infants receive a proper diet so far as vitamins were concerned but the inorganic substances were properly balanced. There were ideal hygienic surroundings; there was a minimum opportunity for infection. During the two years neither a laryngologist nor an otologist was summoned to the ward. Incipient nasal infections were controlled.

When these children left, at the age of two years, they were kept under supervision in their adopted homes. Only one developed a mastoid. In this case it was found that the mother desired to do things just right, so she mixed the baby's milk with cod liver oil, allowed it to stand and then skimmed off the surface content. Removing the fat resulted in a mastoid.

At the age of seven none of these children have a caries tooth.

These infections, due to deficiency diet, are not limited to the nasal sinuses. The result is a nutritive disaster.[6]

Perhaps vitamins and proper hygienic measures play a more important rôle in our climate than in the tropics. Dr. Lambert in a personal communication told me that in Porto Rico a rickets commission found almost 100 per cent malnutrition in the children but only two cases of rickets. One of these was from New York, the other had always lived in a basement. It is the deficiency of vitamins plus something else that causes the sinus infection.

Shurly has shown that gram negative organisms in the nose and throat other than meningococcus, as micrococcus catarrhalis become pathogenic when injected into animals fed on diets deficient in vitamin A; the control rat is not affected. The rats on a deficient diet that lived ten days after inoculation developed necrosis of the liver.

Shurly has also shown that virulence of organism plus resistance of cells determine the degree of infection.

Changing biochemistry often changes the course of disease. He also relates how there is a seasonal variation in the virulence of the bacterial flora of the upper respiratory tract.

From the time we are born until we die we combat the streptococcus. Early in life he is in the lymphoid tissue of the throat, then later in the sinuses, then in the gall bladder, the teeth, the appendix, then he lives in the prostate, the cervix of the uterus, in the colon. It is impossible to cut out all the places in which he lives. By keeping up our immunity, our resistance, or what not, we fight our battle best. Vitamins and proper hygienic measures are important things in this battle.

While the influence of allergy and diet in nasal infections is well understood, the influence of endocrine disorders lacks the definiteness of the others. Their influence is just as important, as is evidenced by the comparatively few cases where remarkable results are secured by endocrine therapy alone.

It is exceedingly difficult to diagnose endocrine disturbances in children. The unruly child will not cooperate in making the observations necessary for diagnosis. It is my custom to refer these children to a pediatrician and to suggest that, if he suspects an endocrine dyscrasia, the proper therapeutic procedure be carried out.

I have seen many cases of infected tonsils with sinus disease in children become quiescent following a period of treatment directed towards the pituitary or thyroid.

In the otologic field the influence of endocrine disturbances is very definite. Drury,[7] in reporting an endocrine study in 1000 cases of deafness, has proven conclusively the necessity of making an endocrine study of every case of progressive deafness when the cause is not thoroughly understood.

The relation between thyroid disease and chronic deafness is very important. I find that the more one investigates the influence of the thyroid dysfunction upon the ear, the more importance does he give to their relationship.

Bunch[8] relates a case of hypothyroidism and deafness where by treating the thyroid dysfunction the hearing increased. On stopping the treatment, the hearing again became less acute.

Fowler's studies of progressive deafness, as it relates to sinus and other infections, are opening up new fields.

The systemic disturbances so often emphasized by Stucky must be considered.

The observations of Carmody and Wasson on sinus infections in children are most interesting. They showed that the only evidence of early sinusitis may be ciliary dysfunction. When there is infiltration of membrane or bone involvement the sinus membrane will not return to normal.

How important it is then that we get these cases early and eradicate the cause. They stressed the influence of outdoor life and general treatment on the condition. They found that as children became old enough to play out of doors the sinus infection improved. They found it difficult to get in any child a series of X-ray plates from infancy to eight years of age that did not show at times diseased sinuses. This is most important.

Displacement irrigation of the nasal sinuses, using lipiodol, has done much to increase our knowledge of sinus disease.[9] By this method not only can the thickness of the lining membrane of the sinuses be determined but changes in its thickness from day to day can be nicely studied.

The study by this method of the blocking of the ostia of the sinuses and the rapidity with which the sinuses are emptied has added important data.

It seems to me that the most far-reaching result of Dr. Proetz's studies will be along physiologic lines as they relate to the sinuses.

The work of Greenfield Sluder on nasal headaches is one of the greatest advances in recent years. His latest book, "Nasal Neuralgia, Headaches and Eye Disorders," is a careful study of certain types of headache and neuralgia of nasal origin which he ascribed to irritation of the sphenopalatine ganglion and the nerve roots connected with it, due to diseases in the neighborhood; he also drew attention to the pain resulting from obstruction of the frontonasal duct, the so-called vacuum headache.

In making practical application of Sluder's work, we must first differentiate between nasal headaches and other types of pain. The success of our efforts will depend almost wholly on this procedure. We must not attack all kinds of head pains with nasal procedures, regardless of their cause.

The observations of Lassel and Fenton[10] as to the mechanism of referred pains has helped clarify our conception of them.

The application of ultraviolet and infra-red rays in diseases of the nose and throat is now on a firm foundation.

Edinow[11] has shown that infra-red penetrates beyond the blood vessels in the skin, heats the tissues, and produces vasodilatation and hyperemia. Ultraviolet rays are absorbed by the hemoglobin pigment of the blood.

Ultraviolet rays applied to the skin produce a local bactericidal effect. The bactericidal substance enters the general circulation. The general radiation of the normal skin improves the health and body resistance.

Such treatments often benefit in early cases of lupus of the palate and larynx. They also improve inflammatory conditions of the mucous membrane which are due to general disturbances.

The local treatment of a lesion with ultraviolet light accelerates repair. It favorably influences the healing and repair of septic wounds. Local treatment of the mucous membrane accelerates repair and regeneration of granulation tissue.

Water-cooled throat lamps should be used in the mouth and pharynx. The use of quartz rods to transmit the light to the site of the infection, I think, is unsatisfactory, as the intensity of radiation is reduced.

Mucous membrane is more sensitive to light than the skin and great care must be used as to dosage.

Two forms of ulcerated throat have appeared in the last few years, or at least have only been commonly recognized during that time: agranulocytosis and monocytosis. In each of these diseases the angina is a secondary expression of a general disease. Each is characterized by ulcerative tonsillitis with an unusual blood picture.

Agranulocytosis seems to be actually increasing in this country and abroad. The appearance of the throat is similar to that of a very severe streptococcic sore throat. The blood shows the typical changes, hemoglobin and red cells, normal or slightly reduced. The number of white cells is greatly reduced, usually to 800 or 900, sometimes slightly more.[12] There

is a complete or almost complete absence of granular cells, with almost 100 per cent lymphocytes. The prognosis is very poor; the therapy is not definite.

Monocytosis differs from the former in that the prognosis is good and the blood picture is different. The number of white corpuscles is normal. The monocytes are greatly increased, rising in some cases to 70 or 80 per cent.[13] Here as in agranulocytosis the therapy is not definite.

Hart[14] states that we should by making careful blood examinations of our severe cases of angina be on the lookout for these two unusual diseases.

Thanks to Mosher, the esophagus is no longer a mystery. Cardiospasm we now know is not a mysterious thing but is a definite condition dependent on definite pathologic conditions. The influence of esophageal webs and exostoses on deglutition has been elaborated.

His work on the regeneration of the lining of the maxillary sinus has been confirmed by Tonndorf.[15]

The most important fundamental change that has occurred in recent years in otolaryngology is the conversion of the specialist in otolaryngology into an internist with otolaryngologic leanings. Today we realize that lesions in our field influence distant parts of the body. Foci of infection produce numerous serious disturbances far remote from the otolaryngologic field. Again, lesions far remote cause disturbances in the ear, nose and larynx. In studying the structures with which we are most concerned we think of the influence of deficiency diet, allergy, of endocrine disturbances, of the anemias, the infections of intestinal disorders, and the whole gamut of general dysfunction.

We no longer look at a patient as one who must be operated upon; rather we are devoting all our efforts to remove the cause and produce a more desirable result. Or we think of other procedures—radium, X-ray, ultraviolet rays, infrared rays—in our effort to secure for the patient the best possible result with the least danger.

Internal medicine, pathology and diagnosis play just as important a part in otolaryngology as in general surgery.

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LXXIX.

SYMPOSIUM ON THE SINUSES.

PHYSICS AND PHYSIOLOGY OF SINUSES.

ARTHUR W. PROETZ, M. D.,

ST. LOUIS.

The physical problem involved in the study of the nasal sinuses is that of the passage of fluids—gaseous and liquid—to and from a rigid chamber through a small opening communicating with an air passage, open at both ends.

At first glance this problem appears to be a very simple one, as the conditions which surround it are certainly not complex; but the forces which control the movement of the fluids in question are numerous and, which is more important, variable. Their resultants are not always obvious.

The fluids concerned are air, normal secretions, inflammatory exudates and solutions employed for diagnosis and treatment.

The physical factors which determine their behavior are pressure, gravity, viscosity, surface tension and temperature.

Before proceeding to the matter of fluid currents, it is necessary to examine thoughtfully the physical characteristics of the sinuses themselves, of their ostia and of the nasal chamber and its outlets.

The sinus is essentially a rigid-walled cavity containing air. The rigidity of its walls, hence the invariability of its air capacity, is especially to be remembered in all problems involving air pressure, for although the lining membrane may be soft and thick, and yielding to the touch of the probe, the *total* capacity is determined by the limiting bony wall, which obviously does not yield to air pressure, positive or negative.

The *relative*, or air capacity of the sinus, on the contrary, is determined by the condition of the membrane, which applies also to the relative patency of the ostium. The important thing is that whatever the air capacity of the sinus may be at the moment (determined by the thickness of the membrane),

it cannot be immediately influenced by positive or negative air pressure. Such changes must be brought about through vascular or lymphatic mediation, and must therefore be relatively slow.

The flow of air through the ostia is determined by their size and the degree of pressure applied, but the latter is influenced to a very great extent by the relative sizes of the nostril and the choana, a fact which has received little attention.

Assuming that there is such a thing as a normal air current in the nose which maintains normal positive (expiratory) and negative (inspiratory) pressures at the ostia, it is obvious that these pressures increase in both directions as the nostril decreases in size. In like manner, the extremes are decreased as the choana narrows (so-called choanal index). Whether the narrowing occurs at the nostril or the choana, the current of air in the opposite nasal chamber increases with a resulting increase in the extreme pressures at the ostia. The pressure variation in the sinuses is of the order of —6 mm. water to +6 mm. water, as measured in the antrum by Braune and Clasen, or —50 mm. to +35 mm., respectively, in forced inspiration and expiration. (See Fig. 1).

Complete blocking of the choana from any cause (atresias, tumors, adenoids) naturally stops all air currents through the ostia so that no interchange of gases takes place excepting a negligible amount through diffusion.

It has been repeatedly observed that in the presence of a complete congenital choanal atresia, the sinuses remain uninfected, whereas, in the case of the acquired postnasal blockades sinus infection is the rule. Tubal infections also commonly accompany the latter, whereas in a case of congenital absence of the nose, including sinuses, recently observed, the ears and the hearing were normal. We leave to the pathologist the task of reconciling these findings.

Too obvious to require more than passing comment are the effects of adjacent structures—septal deformities and turbinates —upon the patency of the ostia.

Posture, however, merits some attention. The sphenoid and the maxillary sinuses are commonly regarded as the poorest drained, in the erect position. The maxillary receives secretions from frontal and anterior ethmoid cells, owing to the

peculiar configuration of the unciform process and the hiatus semilunaris, and its own dependent position. The sphenoid has been suspected of receiving exudates from the posterior ethmoids in certain positions, but it is difficult to see how these positions might be assumed in the course of the individual's normal pursuits. Ciliary action also is effectively directed against it in this region.

Postures in sleep, however, should not be ignored. Many persons have characteristic sleeping habits. The patient who sleeps habitually on his right side offers his left antrum excellent gravity drainage for one-third of the time, while the right is never so drained. The one who sleeps always upon his back depends entirely upon respiratory currents and cilia to empty his sphenoids. The sphenoid cavity with a pneumatized pterygoid process presents the most difficult situation for postural drainage. However, after observing a great many such cells filled with opaque oil, one is forced to the conclusion that in a comparatively healthy sphenoid, posture plays a minor rôle in drainage, for the most tortuous pterygoid pouch empties itself as readily as any other cell in the nose and much more quickly than a diseased cell having natural gravity drainage.

The patency of ostia should be considered relative to the gases and liquids which are to pass through them and which differ widely in their physical properties. Beside the passage of the normal inspired air, our chief concern with the effects of air pressure is in regard to certain forms of treatment.

The simple application of suction to the nostril with the patient in the upright position is an ineffectual means of emptying the sinus, unless its ostium lies at the very bottom and the sinus contents are fluid.

*"To remove a fluid by suction or by postural drainage, from a rigid chamber through a small opening, two conditions are requisite: Its viscosity must be relatively low, and it must completely cover the opening. If the viscosity or the surface tension be high, the exuded drop will not fall away from the ostium, but will be drawn back into the sinus when suction is released. If the submersion of the ostium is not complete

*Quoted from "The Physics of Sinus Drainage," Proetz, A. W., Annals of Otology, Rhinology and Laryngology, Vol. XXXVI, No. 1, p. 23-33, March, 1927.

there can be no effect produced by suction on the contained fluid; hence the uncertainty of simple suction as a diagnostic method. . . .

Grant for the moment that the position of the ostium and the nature of the fluid are favorable for its removal by suction, still other physical restrictions interpose themselves. According to Boyle's law, the volume of a gas varies inversely as the pressure, the temperature remaining constant.

$$pv = km$$

where p is the pressure, v the corresponding volume of a given quantity of gas, m the mass of the gas, and k a constant factor of proportionality.

Assume that a given cell has an air capacity of one cubic centimeter, that it is half filled with a thin fluid and that its ostium is at the bottom, in the optimum position. In order to force out the ½ cm. of fluid, the volume of the ½ cm. of air will have to be doubled. In order to accomplish this the pressure outside the cell must be reduced by ½ atmosphere—a vacuum of 380 mm. of mercury, which is far beyond the limit of safety in the nose. What occurs in practice is, of course, that a very much smaller amount is removed at a time by a very much lesser vacuum often repeated.

If the pressure in the nose be reduced by, say, 1/6 of one atmosphere, the volume of enclosed air will be increased to $6/5 \times 1/2$ cm., or .6 cm., an increase of .1 cm. Therefore, .1 cm. of fluid will be forced out. Larger and smaller cells extrude amounts in exact proportion, not to their size, but to the volume of air they contain.

Therefore, if the contents of the cell are sufficiently fluid, and the head is in the proper position, repeated gentle suction will remove it a drop at a time. Under proper conditions the excursions of respiration (which Braune and Clasen estimate produce in the maxillary sinus an average fluctuation of 12 mm. of water) are sufficient to withdraw fluids from the sinuses. I have frequently observed this in experimenting with solutions introduced into the sinuses by displacement—in fact, some antra may be emptied in this manner without resorting to puncture. In many instances these solutions, which are flavored for ready identification, were pumped out by the

respiratory excursions several hours after introduction, when the head was suddenly placed in a favorable position.

The subject of viscosity receives scant attention in most texts on physics and physical chemistry. In gases, liquids and plastic materials, the term viscosity is applied to the friction between the component molecules of the substance as they pass over one another when changes in the shape of the mass occur. Exudates commonly encountered in the sinuses vary widely in their compositions and in their viscosities, and the latter are usually high, as compared with the viscosities of blood plasma and the transudates. The viscosity of exudates is almost invariably higher than that of the normal secretions. The sinus contents are apt to be rich in mucin, the surface tension is high, and globules form readily.

We must not conceive of the pus in a sinus as being necessarily a thin fluid which readily seeks its lowest level. Instead, it often clings tenaciously to the walls, especially if these are irregular and divided by septa. Changes in the posture of the head may not cause it to shift its position in the sinus unless they are maintained for some time. When patients whose nasal fossæ are literally filled with pus lean forward, the pus does not escape from the nose as does, for instance, the thin fluid of vasomotor rhinitis. No more does the momentary shifting of the patient's head during the application of suction bring about a readjustment of the secretions within the sinuses sufficient for effective evacuation.

I have observed that much of the pus which is evacuated from the nasal fossa by simple suction has been dislodged from the vault of this chamber itself, or from the vault of some meatus where it was at first hidden, the easily distensible membranes of the turbinates and the collapsible cartilaginous portions of the nose squeezing it out under the influence of the suction.

The viscosity of a substance is measured by the tangential force on a unit area of either of two horizontal planes at a unit distance apart required to move that plane with unit velocity in reference to the other plane, the space between being filled with the viscuous substance.

The ratio of the force required to move the one surface parallel to the other, to the velocity of such motion (or

"shear") is known as the coefficient of viscosity. It is expressed by the symbol η.

$$\eta = \frac{\text{F (force)} \times \text{S (distance between faces)}}{\text{V (velocity)}}$$

It follows that in the case of fluids lying on inclined planes, such as secretions in sinuses, the value of V is low where the coefficient of viscosity is high, as the moving force F is limited to the weight of the drop itself.

In subacute inflammations, and still more in chronic ones, exudation is slow, and the coefficient of viscosity of the secretion is high. The movement of the mass under such conditions is that of a semisolid rather than a liquid.

The movement of a thick stream making its way through an ostium is not unlike that of emulsions passing through capillary tubes. The center of the mass moves at the highest velocity, the periphery scarcely at all.

According to Yates, the action of the cilia upon mucous masses is to roll them over and over, enveloping the débris in their path.

Such streams move slowly. Sometimes their surface tensions are so high and their components so elastic that they finally emerge from the sinus in a globular mass which retains its contour in the nose."

A word may be said here in regard to sprays and douches and the solutions employed for this purpose. Sprays follow the passages from nostril to choana which offer the least resistance to the air. The globules are deposited upon the exposed membranes. If there is a free nasal passage, the proportion of the vapor to enter the meatuses is small. If any penetrates the sinuses, the amount must be negligible.

In irrigating or douching the nose, the amount of fluid to enter the sinuses must depend upon the amount of vacuum produced in it, intentionally or fortuitously, during the process, as any penetration of fluid must be attended with the displacement of air. The simple snuffing of fluids is attended by some negative pressure (—50 mm. See Braune and Clasen above), and if a droplet of fluid covers the ostium at the mo-

ment, it will be drawn into the sinus. Larger amounts of fluid may be made to enter a sinus by supplying the necessary posture and fluid and displacing the contained air by means of a vacuum apparatus applied to the nostril.

Of the osmosis of colloids, as it affects sinus problems, only this need be said: That upon it depends the secretion within the sinuses, which determines the fluidity of their contents. And further, that as colloidal systems (which includes both the protoplasm of the living membrane and the products of inflammation which accumulate upon it) are especially sensitive to electrolytes in solution, it should repay us to inquire more closely into the action of salts in various concentrations with a view particularly of improving the conditions of drainage. Digestive ferments are also to be considered for this purpose.

Temperature varies within relatively small limits in the sinuses, and its effects from a purely physical standpoint are negligible.

PHYSIOLOGY.

Much as is known about the behavior—and especially the misbehavior—of the nasal sinuses, their proper function remains a mystery.

Merely an enumeration of the theories regarding the sinuses must suffice here. Skillern assembles them in this order:

1. Remains of rudimentary structures which in lower forms served as adjuncts to the sense of olfaction. (Ingersoll and others.)
2. Adjuncts to olfaction through assistance in distributing air. (Braune and Clasen.)
3. Means of lightening the bones of the skull, to maintain balance. (Vesalius and many others.)
4. Resonators of the voice. (Spiegel and Voltini.)
5. Humidifiers, as an adjunct in lessening the inspired air.

Such cogent objections are advanced to each of these theories as to render none of them completely tenable, and they are named here chiefly to emphasize their weaknesses.

I once added another to the list, to the effect that sinuses are formed by the cleavage of bones, necessitated by an unequal

development of their respective parts, after ossification has set in, though I confess that this theory has weaknesses of its own.

Though the ultimate purposes of the sinuses are not clear, much is known regarding the general physiologic processes which take place in and about them, and these are of importance in diagnosis and treatment. To begin with, the normal sinus is lined with a low, stratified columnar epithelium, for the greater part covered with cilia. Ciliary action was recognized long before the nature of eipthelium itself. It was described by A. de Heide (1683) and A. von Loewenboek (1695) in mollusks and later in the vertebrates. We are not concerned here with the development of the knowledge of ciliary action, particularly since it is not perfectly understood at this day. Certain determined facts, however, concern us.

Cilia are not immutable cellular organs, but may develop in areas and upon cells where they have not previously existed.[1]

They are contractile throughout their entire length. The contractions progress in a wavelike motion from base to tip at an average rate of .24 mm. a second.[3]

These contractions are again synchronized in such a way as to produce a surface wave in the direction required for the proper functioning of the part.

Characteristic of ciliary epithelium is its extreme irritability to mechanical disturbances and a high sensitivity to osmotic pressure.[4 5] According to Kraft, the impulse is transmitted from one cell to the next in the direction of the surge, although McDonald and his associates describe experiments upon the pharyngeal membranes of the frog, in which they were able to control the speed of the ciliary wave propagation by sympathetic and parasympathetic nerve stimulation. They also report

1. Prenant, 1899: Sur la présence d'amas leucocytaires dans l'epithelium pharyngien et oesophagien d'Añguis fragilis. Bibl. Anat. bd. 11, 1899.

2. Mayer, S.: Zur Lebre vom Flimmerepithel visbesondere bei amphibienlarven. Anat. Auz., Vol. 14, p. 69, 1897, and others.

3. Engelman, Th. W.: Ueber die Flummerbewegung. Zentralblatt für Med. Wiss., N. 42, p. 652, 1867.

4. Zweibaum, J.: Sur la survie de l'epithelium vibratile in vitro. Compt. rend. des seances de la soc. de biol., Vol 93, p. 782, 1925.

5. ——— Analyse histophysiologique de l'epithelium vibratile en etat de survie in vitro. Ibid., Vol. 93, p. 785, 1925.

acceleration with epinephrin and ephedrin and retardation with pilocarpin.

Their experiments confirm also the observations that ciliary activity is absolutely dependent, for its function, upon a surface film of moisture, being retarded and finally paralyzed by progressive dehydration. Cold has a similar effect.

The practical value of these observations lies, naturally, in their application to the particular surgical problem in hand, and to my mind, the most important of them insofar as one's conception of infection and its chronicity is concerned is this: The extent, effectiveness and direction of ciliary propulsion are greatly modified by excess of moisture which creates gravity currents flowing over neutralizing ciliary currents. These currents are determined by the amount and viscosity of the fluid and the topography of the surface. Which translated into the language of the laryngologist, means that so long as the foreign body (bacterium) is microscopic in size or is sufficiently sticky, it can be propelled toward the ostium by the cilia. But once infection sets in and exudation occurs, the cilia fail to cope with the situation. (See Fig. 2.)

For convenient visualization of the situation, multiply all these minute measurements by 100, and regard a 30 mm. antrum as a ten foot room. The ostium in proportion becomes an eight inch ventilator near the ceiling. The cilia in such a chamber would be represented by a fine velour wall covering having a nap not over 1/40th of one inch in thickness!

The length of the cilia is roughly comparable to the diameter of a red blood corpuscle, microorganisms which are considerably smaller being readily carried along on the ciliary wave. (See Fig. 3.)

By peeling off sections of ciliated epithelium, mounting them on a slide, and permitting them to propel particles of known weight up an inclined plane, Bowditch estimated the amount of work done by the cilia. He states this to be in the neighborhood of 7 gram-millemeters per minute (equal to the raising of 7 grams to a height of one millimeter). In terms of the ten-foot room again, its velvet walls would lift a weight of a pound and a half a distance of 3.93 inches a minute. At this rate it should require a half hour to propel the mass from the bottom of the sinus to the ostium.

The pathways along which the cilia of the nose direct drainage from the sinuses to the pharynx have been described by Yates and others, but do not immediately concern us here. The lymphatic drainage also presents no peculiarities from a physiologic standpoint. It is chiefly by way of the retropharyngeal nodules. Mucous glands are less numerous in the membranes lining the sinuses than in the nose. The film of mucus covering the healthy sinus wall is extremely thin—in fact, just sufficient to maintain physiologic ciliary action, and no more.

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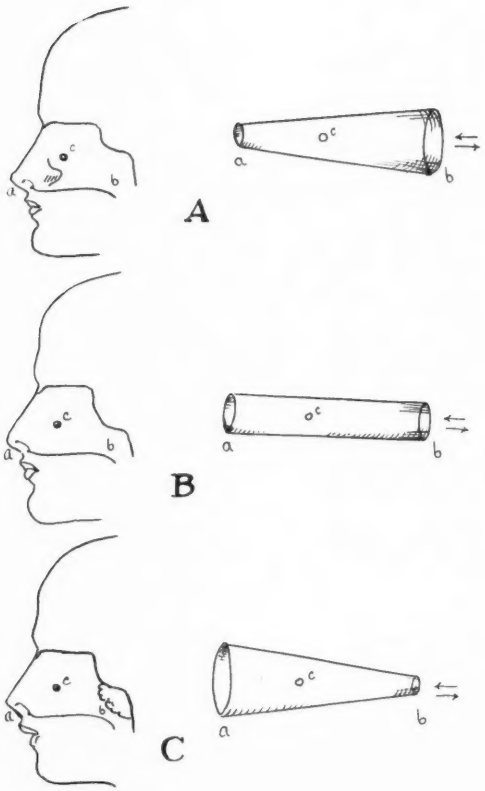

Fig. 1—Presupposing a given fluctuation of positive and negative pressures in the pharynx, occasioned by the act of respiration, the oscillations of pressure at the ostium (c) depend directly upon the relative sizes of the anterior nares (a) and the posterior nares (b). Diagram B represents the average situation. A represents a constricted nostril, an anterior obstruction and a fairly large choana. In this condition pressure variations at (c) are increased. Diagram C represents a wide open naris and a posterior orifice obstructed by adenoids. In this case oscillations of pressure at (c) are much reduced, due to rapid equalization of pressure through the wide open nostril (a) and the impediment to pressure changes at (b).

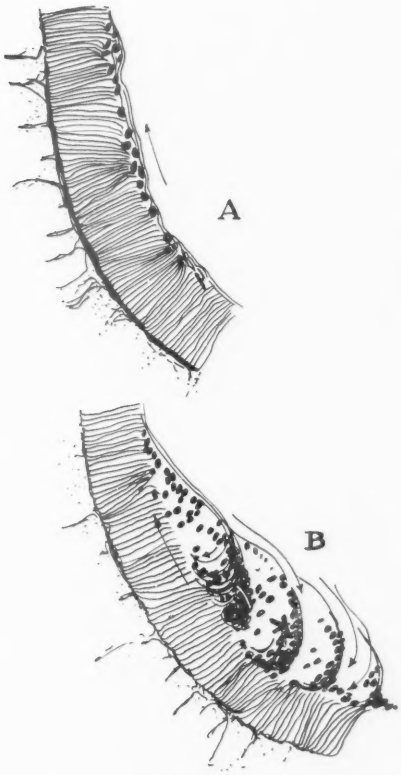

Fig. 2—(A) Diagram of cocci moving over the surface of ciliated epithelium. Note the thin layer of moisture. When this fluid is increased in amount or density, as is the case in inflammatory exudates, counter currents develop (B) which nullify ciliary propulsion.

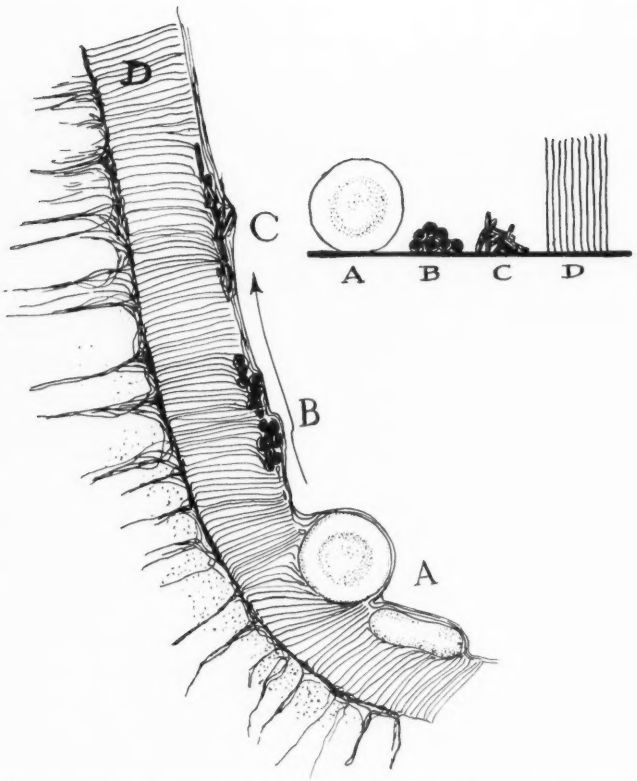

Fig. 3—Diagram indicating the relative sizes of red blood corpuscles (A), cocci (B), bacilli (C), and cilia (D). The microscopic bodies being propelled by the cilia are coated with a thin layer of mucus. A maxillary sinus drawn to the scale of the cilia here represented would be 162 feet high!

LXXX.

PATHOLOGY OF SINUSITIS.*

By Frank B. Kistner, M. D.,†

Portland, Oregon.

In this section of the symposium I have no intention of going into academic pathology. I will show a number of slides of gross and microscopic specimens secured at operation and will make the effort to connect them up in a practical way with the history and treatment of the cases.

The first three slides are shown to demonstrate the two extremes of gross pathology; also the lack of relation between the extent of the tissue changes and the seriousness of the sequelæ.

Case 1.—This case reveals the lining of an antrum with many polyps and cysts attached, as shown by Plate No. 1. The largest polyp, marked A, was hanging in the choana. At the Caldwell-Luc operation the mucoperiosteum was elevated over the entire antrum and the choanal polyp still attached was drawn back into the antrum. It was not attached near the ostium but to the external lateral wall of the antrum. This illustrates the mechanism of the recurrence of polyps of this type. This one if evulsed leaves two or three others in the antrum that may make their exit at the same place. Plate No. 2 shows the hyperplastic lining of the sphenoid and an ethmoid cell, but these sinuses show a different type of pathology than is present in the antrum. Microscopic sections of the antrum show very little inflammatory activity. The connective tissue shows typical mucoid degeneration. In the ethmoid cell, however, there is a definite inflammatory activity, with marked fibrosis and the type of pathology usually seen in hyperplastic sinusitis.

Case 2.—In Plate No. 3 is a picture of the extremely thin linings of two antrums showing very meager gross pathology.

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*Read in the Symposium on Sinusitis, Pacific Coast Oto-Ophthalmological Society, Salt Lake City, June, 1929.

†From the Department of Otolaryngolgy in Cooperation with the Department of Pathology of the University of Oregon Medical School.

Throughout most of its extent the mucous membrane appears normally thin and in a few places small sessile polyps are seen. The diagnosis in this case was made by a thick mucoid material in the washings.

In the first case with the gross pathology the only complaint was nasal obstruction and repeated colds, otherwise the patient was apparently normal. In the second case, with the very meager pathology and thin membrane, the patient was seriously ill with myocarditis due to the sinus infection.

Plate No. 4 is a microscopic section from Case 2, shown merely for comparison with the following pathologic sections as an example of a normal mucous membrane lining the paranasal sinuses. There is seen no leucocyte infiltration, edema or fibrosis. The epithelium is intact and the entire section is very thin.

Case 3.—Plate No. 5 is a picture of the extremely thick pyogenic linings removed from the antra of a young woman who was allergic. She had an inheritance of allergy; her mother, maternal aunt and self all being afflicted with seasonal hay fever. She also had chronic bronchitis and perennial asthma.

She had had an intranasal ethmoidectomy and intranasal drainage of both antra two years before I saw her, with no relief of the asthma, bronchitis or hay fever. The ethmoid area was well healed. The antra still showed active infection. This plate of the gross specimens and the section in Plate No. 6 demonstrate the pathologic activity that continues for two years after perfect intranasal drainage. After complete exenteration of her antra, the bronchitis and asthma were relieved, but the seasonal hay fever continued.

The history of this girl illustrates very beautifully that sequence of events that we have quite frequently, although not always, in asthma; that is, an underlying allergic condition which lays the foundation for a sinusitis; the sinusitis producing a bronchitis with subsequent asthma. In the pathogenesis of this case it is probable that the bronchitis produced asthma, and the cure of the sinusitis relieved the bronchitis with cessation of the asthma.

Plate No. 6 shows marked inflammatory activity with a marked infiltration of polymorphonuclear neutrophiles and hyperplastic changes in the epithelium. From the history of

this case one would expect a massive infiltration of eosinophiles, but in spite of the fact that this was a definitely allergic case these leucocytes were relatively inconspicuous.

There are many phagocytic leucocytes seen emigrating through the epithelium. This demonstrates purulent exudation. It will be noted that the cilia present on the cells show a degenerative change.

Case 4.—The next five plates are from a case of retrobulbar neuritis. They are pathologically important because they illustrate the nonsuppurative state. They are interesting because they demonstrate the clinical importance of latent sinus infection. There was nothing in the patient's history, past or present, to suggest chronic sinus infection, but, as you can see from the microscopic sections, there is unmistakable evidence that this is the subacute stage of an exacerbation of latent sinusitis in all the sinuses on the left side. The lining of the left antrum is seen in Plate No. 7, showing hyperplastic or polypoid changes. The specimen was everted on a ball of cotton after removal from the antrum. The left sphenoid and one of the ethmoid cells are seen in Plate No. 8.

The lining of the right antrum is seen in Plate No. 9. The neuritis was on the opposite side. This plate shows a small amount of hyperplasia in the epithelium with fibrosis of the submucous connective tissue, hyaline hypertrophy of the basement membrane and perivascular fibrosis. There is present on this side a chronic inactive process.

There are areas in the sections from the left sinuses showing the same chronic changes, but in addition to the chronic fibroses the microscopic sections of the left antrum show a great deal of subacute pathologic activity. There is marked edema and thickening. The epithelium has lost its typical columnar cells, and a degenerated type of cubical cell has piled up. No cilia are present. In Plate No. 10 the edema and metaplasia of the epithelium to degenerated nonciliated stratified cubical cells can be readily seen.

The left sphenoid shows pathologic processes that are identical with those in the antrum of this side.

Examination of the cellular infiltration reveals the presence of many eosinophiles characterized by their bilobed nuclei as

seen in Plate No. 11. Many plasma cells and lymphocytes are also present but there are practically no polymorphs seen.

Eosinophilic infiltration was pronounced in the case, yet there is no clinical evidence that the patient was allergic. We take infiltration of eosinophiles to be a reaction against toxic products. The eosinophile is not a phagocyte.

Case 5.—Shows very gross thickening in the antra of a child nine years old, afflicted with chronic chorea for three years. She had been operated on for tonsils and adenoids with no relief. Recovery followed exenteration of her sinuses. In Plate No. 12 is a portion of the left antrum, showing the ostium on the right. The fragment on the left has been sliced from the thickened membrane and turned on its side. Its thickness, as revealed by the adjoining centimeter scale, is over half a centimeter. The other antrum is seen in Plate No. 13. This specimen is everted on a ball of cotton. The ethmoid and sphenoid cells had the same type of pathology. The microscopic pathology is similar to that of the next case.

Case 6.—The following pathologic study is from a suppurative pansinusitis in a girl, fourteen years old, who had chronic bronchitis. Several intranasal operations had been done without relief of the sinusitis or bronchitis. She was cured after exenteration of the infected sinuses. The gross examination of the mucous membranes showed them to be slightly increased in thickness—not more than a millimeter and a half.

In Plate No. 14 there is seen very little increase in thickness, but, as can be readily seen, there is marked pathology with much edema and cellular infiltration of the tissues. There is a small area in the epithelium where an ulceration is forming. The epithelial cells are undergoing dissolution at this point. Leucocytic infiltration is more dense here. Elsewhere the epithelium is intact. A number of infected tuboalveolar glands are buried deep down in the spongy layer of connective tissue. The duct leading down to the infected glands is shown. This periglandular condition shows that we have something more to deal with than mere surface infection.

In Plate No. 15 is seen the compact periosteal layer in which there is less pathologic activity. The greatest reaction is limited to the softer connective tissue which lies above the periosteal stratum and particularly about the deep lying glands.

A portion of the surface epithelium is seen in Plate No. 16. It is plain that the epithelial cells are almost unchanged. Normal cilia are seen. This type of epithelium covers almost the whole sinus.

Polymorphonuclear leucocytes can be clearly seen emigrating between the columnar cells. These come up from the connective tissue and pass through the epithelium in the manner shown in Plate No. 16. I think it is important to bring out the point that we have a purulent exudate with intact epithelium. Ulcerations are very uncommon, and, when present, play a minor part in the purulent exudation.

This case demonstrates again the futility of simple drainage operations in certain conditions.

Case 7.—The next three specimens show cystic formations. In Plate No. 17 is seen a large serous cyst in an antrum lining. This cyst was much larger before we aspirated a portion of the contents for culture. We have found that in a little less than 50 per cent of our cases the contents of these serous cysts give growths of pathogenic organisms on culture. Microscopic sections of the lining of this antrum show a great number of microscopic cysts.

Case 8.—In Plate No. 18 are the linings from two antra with purulent sinusitis. When these membranes were taken out and spread on cardboard they looked like pieces of skin from an individual with smallpox. Some of the cysts had openings through which purulent contents were draining, but most of them were closed cysts.

In Plate No. 19 is seen the microphotograph of a cystic abscess containing mucopus. This is a very small cyst or a microscopic cystic abscess. The epithelium lining the cyst is intact in places.

It is usual to find numerous smaller cysts of microscopic size in the presence of larger cysts.

Case 9.—The next microphotograph demonstrates mucoid degeneration of the epithelium as commonly seen. The columnar cells have all become goblet cells and are disintegrating. In Plate No. 20 the mucoid epithelial products and numerous eosinophiles can be seen flowing over the surface of the membrane.

Case 10.—Another type of epithelial change is seen in Plate No. 21, which shows a marked metaplasia of the epithelium in an old chronic pyogenic sinusitis. The normal single layer of columnar ciliated cells has been changed by the chronic infection to a stratified layer of nonciliated cubical cells. The epithelium is seldom lost in sinus infections, but usually undergoes the various degenerative changes seen in this series of plates.

There are certain interstitial accumulations of lymphocytes frequently seen in sinusitis which have never been described before. These structures resemble the so-called "Flemming's secondary nodules," recently described by Wilhelm Ehrich of the Rockefeller Institute. These nodes, according to Ehrich, are the result of a reaction to infection and are not germinal centers in lymphoid tissue as Flemming supposed. In Plate No. 22 is seen such a formation with large, clear vesicular cells in the center and a definite ring of lymphocytes around the periphery. Plate No. 15 shows a similar arrangement of lymphocytes. We believe these to be definite structures developed as a result of infection in the sinuses.

It is interesting to observe repair in sinuses that have been operated upon. In Plate No. 23 is seen a microscopic section from a healed antrum after subperiosteal exenteration of the lining. I have biopsies from eight patients who had subperiosteal exenteration. This one shows a definite stratified squamous epithelium like skin. The others show scar tissue with cubical or columnar cells in the overlying epithelia.

A short time ago some experimental work was done on dogs to determine what happened after a sinus was denuded of its lining. The experimenters curetted the "antrums" of dogs; and the regeneration was so rapid that the new epithelium grew over the blood clot before it was absorbed, and not only the ciliated epithelium but also the subepithelial tissues, glands and bone were "regenerated."

In none of our biopsies have we seen regenerated glands or ciliated epithelium.

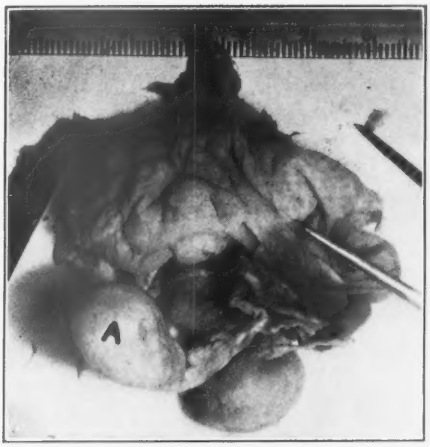

Plate No. 1. Marked pathology grossly with no systemic complaint. The polyp marked "A" was hanging in the choana and was attached on the external lateral wall of the antrum.

Plate No. 2. Ethmoid and sphenoid from same case as above. The sphenoid shows a dusky red inflammatory activity. Both are hyperplastic.

Plate No. 3. Very thin membranes from antra. At point "A" is seen a small sessile polyp. This case was seriously ill with myocarditis.

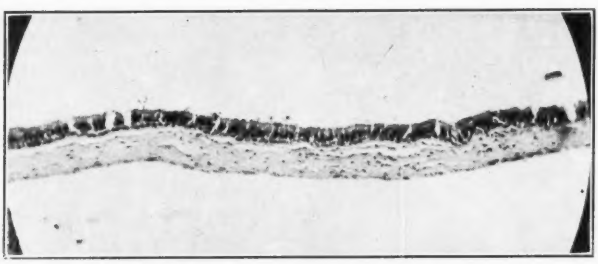

Plate No. 4. This is an example of a normal appearing area taken from a thin portion of the above. Microscopically there is no edema, no fibrosis, no leucocytic infiltration, and the epithelium is composed of a definite layer of pseudo-stratified columnar ciliated cells. No goblet cells are present.

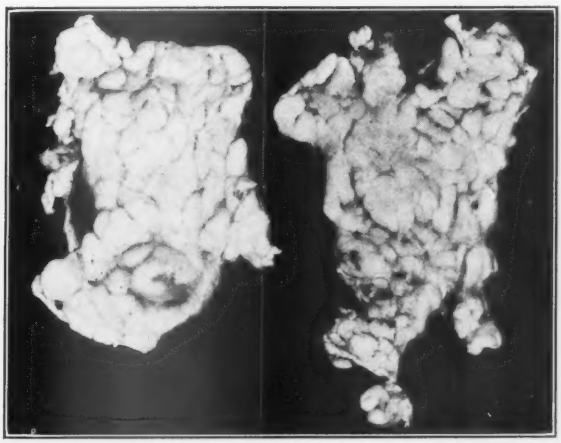

Plate No. 5. Very thick roughened pyogenic linings from the antra of an allergic patient. Good intranasal drainage was present for two years but pathologic activity continued.

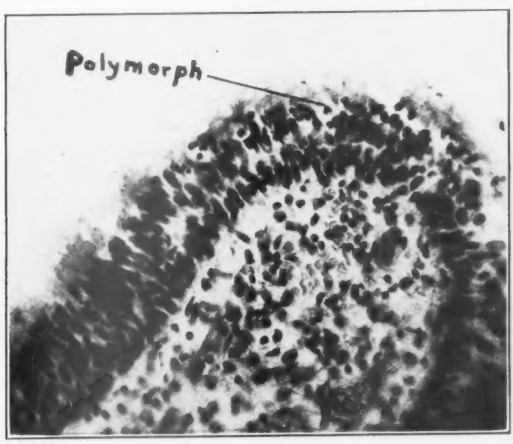

Plate No. 6. Microscopic sections show degeneration of the epithelium with dense infiltration of polymorphs and exudation of these leucocytes through the epithelium. Edema is moderate.

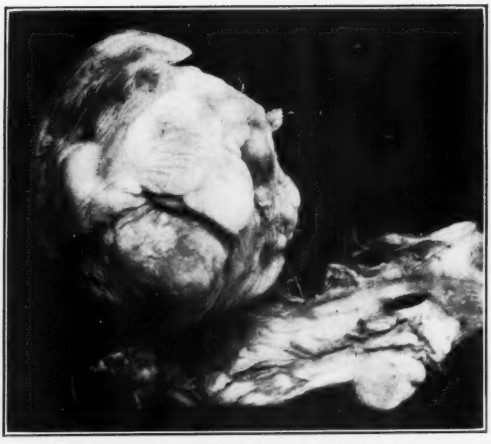

Plate No. 7. Left antrum from a patient with retrobulbar neuritis on this side. Specimen is inverted on a ball of cotton. Grossly there is thickening and polypoid changes. Case IV.

Plate No. 8. Left sphenoid and ethmoid cell from same case. The same kind of pathology is present in these sinuses. The opposite side has little or no pathologic change. Case IV.

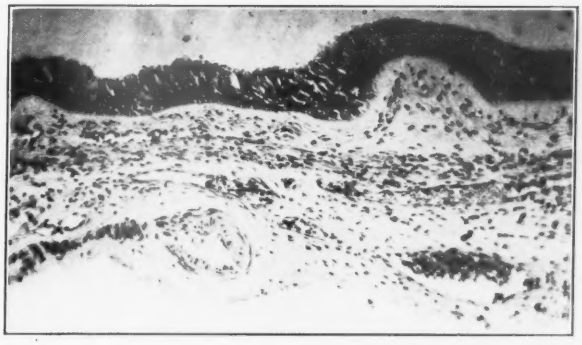

Plate No. 9. Right antrum showing a chronic fibrous condition with a thickened basement membrane and fibrosis of the arterioles. Case IV.

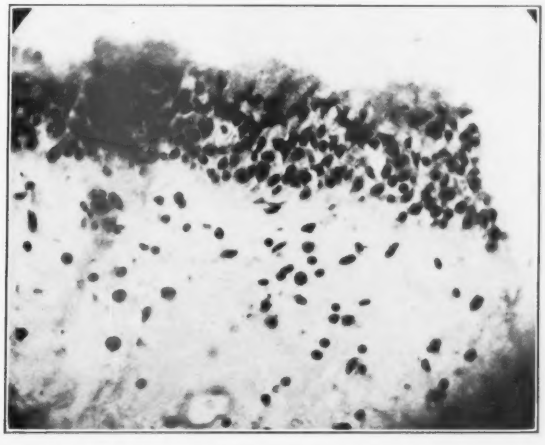

Plate No. 10. Left antrum showing subacute activity with tremendous edema and loss of cilia. The epithelium is degenerated, the columnar calls have been replaced by cubical cells with very poor cell boundaries. This same change is also present in the sphenoid of this side. Case IV.

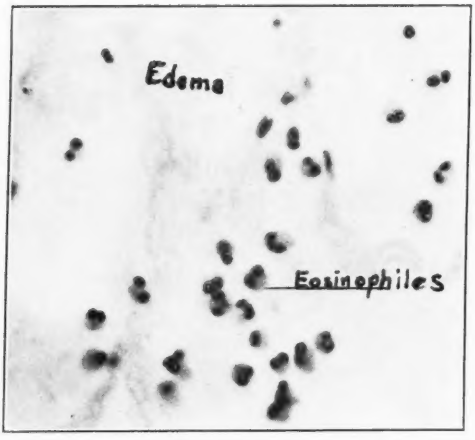

Plate No. 11. High power microphotograph showing typical eosinophiles with bilobed nuclei and marked edema in the left sphenoid Case IV.

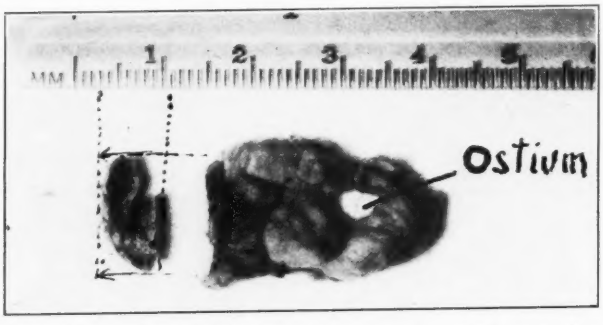

Plate No. 12. Gross thickening in antrum of a child with chronic chorea. The piece on the left has been cut and turned on its side so its thickness can be seen. It is over half a centimeter thick.

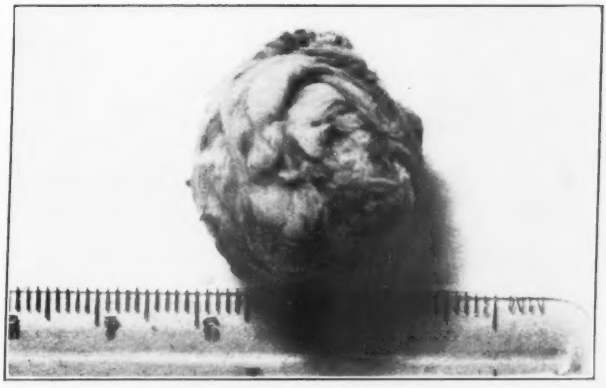

Plate No. 13. Antrum from case with chronic chorea inverted on a ball of cotton. The chronic pathologic condition is bilateral.

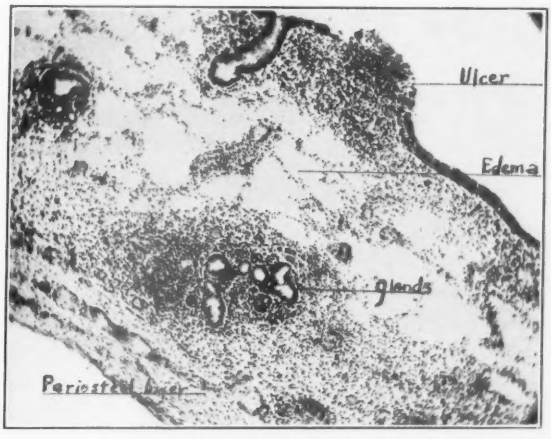

Plate No. 14. Microscopic appearance of antrum from case with chronic bronchitis. Deep seated infection is seen around the glands. Marked edema is present. There is an ulcer forming in the epithelium where the cells are undergoing necrosis. Case VI.

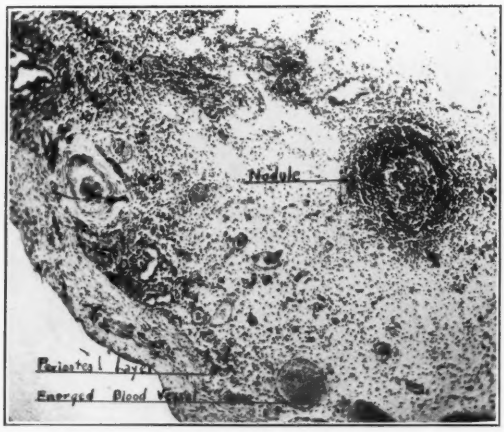

Plate No. 15. Infection is deep seated but is most marked in the loose spongy connective tissue. A lymphoid collection is seen. Case VI.

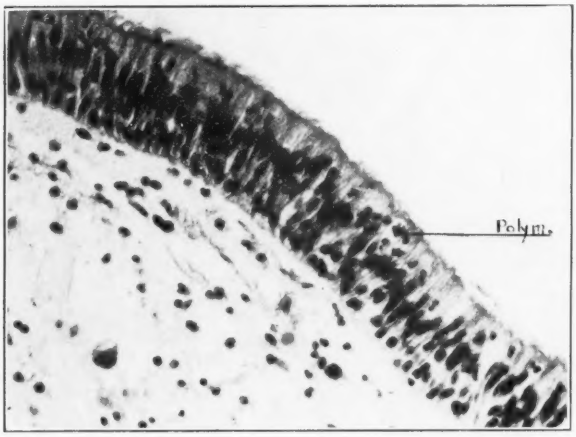

Plate No. 16. High power view of epithelium in the above case showing ciliated columnar cells and emigration of polymorphs between them.

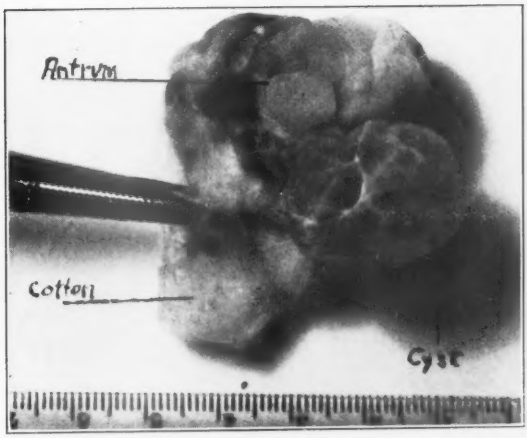

Plate No. 17. Antrum lining with a large serous cyst attached. The lining is inverted on a ball of cotton after removal.

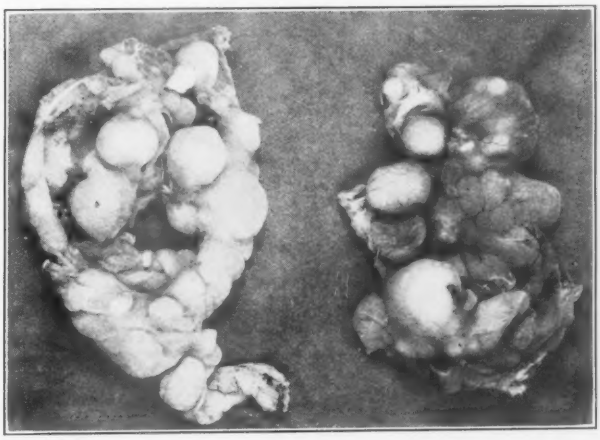

Plate No. 18. Multiple cystic abscess of moderate size in both antra.

Plate No. 19. Microscopic cyst the result of dilatation in an infected gland.

Plate No. 20. Mucoid degeneration of the epithelium in an allergic patient. Note the extensive formation of goblet cells and distintegration of the columnar epithelium. Many eosinophiles are present in the exudate.

Plate No. 21. Degenerative metaplasia in chronic pyogenic sinusitis. The ciliated columnar cells have been replaced by a thick epithelium composed of a multilayered cubical cell structure.

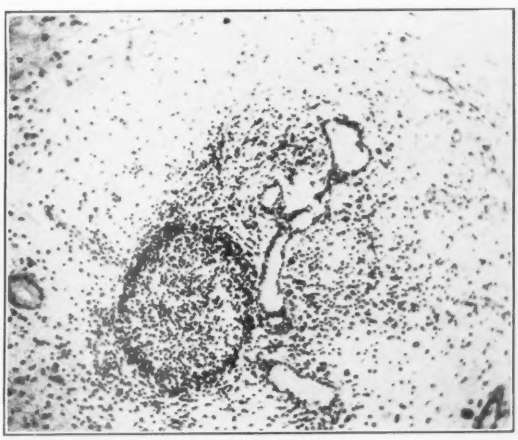

Plate No. 22. Flemming's Secondary Nodule seen in antrum lining of an allergic patient. These are so-called germinal centers of lymphoid tissue but are only seen in infected sinuses.

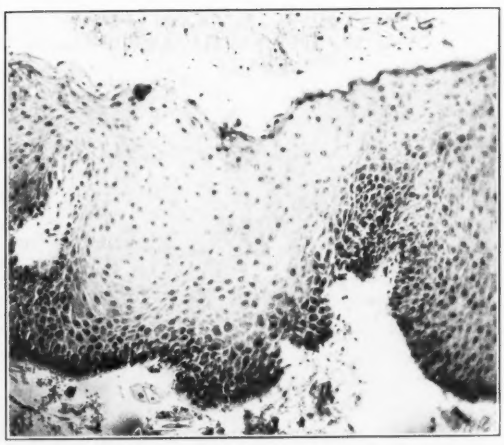

Plate No. 23. Stratified squamous epithelium found lining an antrum several months after a complete subperiosteal exenteration of the original lining.

LXXXI.

GENERAL SURGICAL PRINCIPLES EMPLOYED IN THE TREATMENT OF CHRONIC DISEASE OF THE NASAL SINUSES.*

By Edward Cecil Sewall, M. D.,

San Francisco.

Of the principles important in the surgical treatment of chronic sinus infection, proper drainage is paramount. By this term aeration of the cavity is implied. A noncollapsible cavity can only lose its contents freely by the action of gravity when the place formerly occupied by drainage is replaced by air. In considering this question of proper drainage we come face to face at once with the real difficulties of the problem presented. Drainage of a pus collection in most of the fields of surgery implies the incision into the cavity and the subsequent collapse of the soft parts, leading rapidly to obliteration of the infected space. In the historical development of surgical technic, this simple manner of incision rewarded the surgeon with a cure in many diseased conditions. It still suffices in most localities. However, when this simple treatment was applied to treatment of an empyema in the chest, it was found wanting. The surgeon eventually found it necessary to resect one or more ribs to allow the abscess cavity to collapse. This principle then was added to our surgical armamentarium and was applied to other regions when inflexible walls interfered with cavity obliteration.

Early successful work on the accessory sinuses of the nose frequently employed this principle, and it must be recorded, to the honor of Kuhnt and others, that freedom from disease frequently crowned their efforts. However, the task of the modern rhinologic surgeon is not so simple. Two excellent reasons are at once apparent to explain the difficulties with which he is faced. They are, first, the unsightliness of the

*Presented before the Seventeenth Annual Meeting of the Pacific Coast Oto-Ophthalmological Society, Salt Lake City, July, 1929.

resultant depression where obliteration can be obtained, and second, the difficulty of obliterating certain of the cavities. These factors represent the key to the supreme difficulties encountered in accessory sinus surgery. Nowhere else in the body is the surgeon given the problem of a diseased cavity which he is expected to cure without obliteration of the infected space.

The general surgeon opens an abscess, the pus is evacuated, the walls collapse and the cavity heals. The abdominal surgeon takes out a diseased appendix or opens an abscess in the abdomen and the soft parts press in and obliterate the abscess cavity. The orthopedic operator cleans a septic collection out of a bone in the leg and is only pleased when the soft parts draw in and heal his wound, possibly with an unsightly depression. Drawing nearer to our own field, we see the brain surgeon seek and drain a cerebral abscess. In view of the possibly successful outcome, he gives little thought to the cosmetic result. Even in our own otologic work, we are not held particularly ruthless if it is necessary to occasionally leave a depression in a recalcitrant mastoid. No sympathy, however, is accorded to the rhinologic operator who employs this same great surgical principle in the treatment of an infected sinus cavity. He is set the difficult task of obtaining a cure without collapse of the bony walls of the sinus. Killian broke away from his contemporaries and success rewarded him completely where correct surgical principle was adhered to. The upper regions of his sinus cavities were obliterated and healed completely. The lower parts did not always heal, because of his reluctance to remove the orbital ridge so essential to facial configuration. The removal of this ridge allows of complete frontal sinus obliteration and leads to a cure in practically all cases of frontal sinusitis. Fear of deformity denies us this panacea except in exceptional cases. In the face of these difficulties the modern rhinologic surgeon has struggled and has achieved and is achieving a fair measure of success. He has taken his problem as he found it and has depended for a cure in most cases upon the drainage and consequent aeration of these cavities. Nature is kindly where her physical dictates are followed, and the natural tendency of the body tissues to return to normal will lead to freedom from discharge and

granulation tissue in a large proportion of diseased sinuses where free drainage is obtained and maintained.

I have been assigned, in this symposium, the general surgical principles of treatment. Under this heading I include the surgical diagnosis and must emphasize that I have obtained great assistance by the use of the cytologic method of diagnosis.

Presuming that all nonsurgical methods of treatment where applicable have been exhausted, the surgical problems may be presented in the following order:

1. *Constructive Surgery.*—Before the sinuses are attacked by our more or less classical methods, all constructive surgery that might effect a cure should be carried out. Under constructive surgery is included the removal of tonsils and adenoids and correction of obstructive septal deflections. After such constructive surgery sufficient time should elapse to determine its value before more radical measures are resorted to. Hygienic and climatic conditions will sometimes prevail after such constructive measures have been employed.

2. *Anesthesia.*—I take this fitting time to thank Dr. Eugene Lewis,[1] who follows me on the program, for having brought to my attention the value of scopolamin and morphin combined with local anesthesia. I consider such combined anesthesia a most important factor in the development of sinus surgery. It makes it possible to apply to the living the technic worked out on the cadaver. Where intranasal surgery is employed the topical application of cocain combined with adrenalin, or the injection of novocain under the mucosa, has been the method in common use and usually will suffice to give anesthesia. In doing a complete intranasal ethmoid exenteration, however, it may occasionally be advisable to block off the anterior and posterior ethmoid nerves through the orbit as developed in my external fronto-ethmo-sphenoidectomy.[2] This is particularly helpful when the upper regions are full of polypi. It is difficult in such cases to obtain good anesthesia.

The control of pain in extranasal sinus surgery is accomplished completely in most cases by nerve blocking combined with a small amount of cocain applied topically. For the combined operation of fronto-ethmo-sphenoidectomy the ethmoid

nerves are blocked by passing a needle along the mesial orbital wall and infiltrating the tissues about the nerves as they pass inward from the orbit into the nose. The supraorbital and supratrochlear nerves are affected simultaneously with the ethmoid injection, and also by injection at or near their point of emergence from the orbit. I depend upon the topical application of cocain for anesthesia of the sphenopalatine and other sensory fibers in the region of the nasopharynx. However, where indicated, the sphenopalatine ganglion may be reached with the needle and all its branches blocked.

Anesthesia for the radical antrum operation may be obtained in the following manner: Cocain is applied in the nose by first touching up a few points lightly. The nerve blocking with novocain is then started. After a few drops of the 1 per cent solution have been injected into the tissues, three minutes are allowed to elapse before more is used. This interval is well employed by returning to the cocainizing of the nose and allows the patient to accommodate himself to the drugs to the end that he is rarely upset by the symptoms described as "adrenalin reaction." I do not try to gain anesthesia in the nose at once, but aim to return at intervals and touch essential areas, particularly under the inferior turbinate and in the middle meatus. Anesthesia is satisfactory by the time the operation through the antrum has advanced to the point where nasal insensibility is necessary. Anesthesia for the radical antrum operation is obtained for the most part by infiltration in the region adjacent to the pterygopalatine fossa. This desensitizes the nerves as they enter the antrum and obviates for the most part the use of local anesthesia in the antrum itself. It is not necessary to reach the sphenopalatine ganglion itself—possibly it is better not to do so. In such event the infraorbital nerve is not desensitized. To reach this nerve it is best to make one injection by passing the needle upward from the gingivolabial region. It is not necessary to enter the infraorbital foramen at this time, as that can be done and a few drops of solution deposited there after the incision has been made and the tissues of the face have been raised and the nerve exposed. The area of distribution of the anterior palatine nerves may be desensitized by injection of a few drops of novocain at their exit points on the hard palate.

3. *Control of Hemorrhage.*—There is much less tendency toward bleeding under local than under general anesthesia. This is true even where local anesthetics are used in both instances. The best work cannot be done in the presence of bleeding. Proper hemostasis reproduces almost the condition of the dissecting room. Hemostasis may be satisfactory in some cases from the topical application of cocain and adrenalin. However, just as anesthesia is more satisfactory when the nerves are blocked, so is hemostasis much surer and more complete when the vessels supplying the region have been ligated. I ligate the anterior and posterior ethmoid arteries and the sphenopalatine in operating upon the upper sinuses by the external route. In the former the ligatures are applied in the orbit. In the latter the ligature is passed around the vessel where it runs across the body of the sphenoid. This allows the performance of technical details otherwise impossible.

The terminal branches of the internal maxillary artery may be exposed when working on the antrum,[3] and ligated or clamped off. These control all the blood supply to the nose except the ethmoid arteries. I have not brought this ligation to any great practical fruition, but have found it workable on the cadaver and have performed it several times on the living under both local and general anesthesia. It may lend itself sometimes as a measure to be considered in intractable bleeding from the nose. It certainly would seem more advisable than ligating the carotid.

4. *Intranasal Surgery.*—Intranasal surgery on the sinuses has a definite sphere of usefulness. The simple amputation of the anterior end of the middle turbinate may be beneficial, but is apt to be disappointing in the cases of sinus disease serious enough to warrant any operative measures. This is also true of partial ethmoidectomies. I think that rarely will diagnostic acumen be keen enough to point out the particular ethmoid cell to be opened; also, it is conceded that the question of disease in an opened ethmoid or sphenoid sinus cannot be determined by the naked eye. It has been necessary to consider the ethmoid mass as a whole in determining the question of disease. The differentiation of sphenoid from ethmoid pathology has been difficult, but the X-ray, lipiodol and the cytologic examinations hold out encouragement for finer discrimination. One of

the assistants of our clinic has recently run a series of cytologic examinations of the sphenoid that is interesting.

Intranasal operation on the ethmoid sinuses may be satisfactory in certain conditions. Its applicability, to a certain extent, can be determined by the preoperative X-ray study. Such a method cannot be expected to give the best result where there are supra- and infra-orbital ethmoid cells extending outside the plane of the lamina papyraceæ. Other factors affect the value of this method of operating. Ethmoid cells with very dense walls, easily handled in the dissecting room or when working by the external route, would tax the courage of most of us to open intranasally. Hemorrhage, which may at any time be disturbing if the ethmoid vessels are ruptured, adds to the difficulties of this route. Finally, the inability to completely remove the floor of a deep sphenoid, where sphenoidectomy is combined with the intranasal ethmoidectomy, interferes with the cure of that sinus.

Intranasal surgery for the relief of chronic frontal sinus disease is limited in usefulness. Personally, I do not employ it. To enlarge the frontal opening may be technically possible; to keep it open is more difficult and the relief afforded by such meager drainage is problematical. I think I may state fairly that this method has not the approval of leading surgeons. The intranasal antrum operation has many advocates and gives good results. This is especially true when the anterior end of the inferior turbinate is removed. No sinus operation gives 100 per cent of cures, but I am convinced that the radical operation, based on the Caldwell-Luc principle, with certain modifications, comes much closer to the ideal desired than the intranasal operation.

5. *Extranasal Surgery.*—The extranasal approach certainly expresses the last word in nasal sinus surgery. It divides itself in my hands into two major operations—one the radical, modified Caldwell-Luc operation on the antrum, the other the fronto-ethmo-sphenoidectomy. All of the sinuses in the head can be operated upon radically by these two methods. Where the frontal sinus is under consideration, we usually find that there is more or less disease of the ethmoid group, often including the sphenoid. In such a case one operation is capable

of handling all three groups. However, if the disease is confined to the frontal sinus, only enough of the ethmoid mass is removed to give direct drainage downward into the nose. Where the ethmoid cells alone are diseased, they are reached through the same incision and only such ethmoid cells as wished are exenterated. As it is impossible to always exclude disease in the frontal sinus preoperatively where ethmoid disease exists, it is of immense value to be able to open that sinus and determine its condition. If not diseased it is not disturbed.

If the frontal sinus is diseased, the lining is removed as completely as possible. This is not easy where the anterior walls are left intact, and I believe it is impossible with such technic where the sinus is of large size. Draining downward through the ethmoid region into the nose, the frontal sinus will frequently become entirely well following the procedure. The fact that it does not do so in all cases is a source of great concern and is the blot on the escutcheon of sinus surgery. The reason for the failure to heal is lack of proper drainage, due to the closing down of the opening into the nose before healing has taken place. This occurs even in the Killian type of operation, which gives opportunity for the eradication of all disease under direct vision. Many of the cases where healing fails have doubtless been incompletely operated upon, and the opportunity to obtain a cure is lost before retraction at the inner angle of the orbit has taken place. When once this retraction has occurred, subsequent reoperation, where necessary, is fraught with added difficulty. Application of the Lothrop principle is excellent, but the space gained is often narrow and complete healing does not always occur. Attempts have been made to overcome this fundamental objection to all types of nonobliterating frontal sinus operations. Drainage tubes have been kept in place for weeks, sounds have been passed, mucous membrane has been implanted, but still a certain percentage of failures dampens the enthusiasm of the most ardent worker. What to do with such cases is a problem. In some of them the ethmoid and sphenoid regions are apparently fully healed. It is difficult to determine without operating the exact condition of the frontals. The X-ray is not helpful after a cavity has been operated upon. The only sure way I know of clearing up diseased frontals in these cases, if found at reoperation, is through oblit-

eration of the sinus. This I hesitate to advise. I think, however, that the obliterative technic will come to be more frequently applied in cases where necessity demands a cure.

I am pleased with the results of ethmosphenoid surgery carried out according to my technic, and I am encouraged to feel that the ethmoid cells can all be obliterated and a cure obtained in most cases. The ligation of the ethmoid arteries and the block anesthesia gives every opportunity for thorough and complete exenteration. In none of my cases, even in those not entirely satisfactory, has there been the recurrence of granulation tissue and polypi so often described as the aftermath of ethmoid surgery. I believe that the technic I have described for handling the sphenoid is standing the test of time. The ligation of the sphenopalatine artery has become a matter of routine in this technic. The carrying out of the surgical principle heretofore given requires a great deal of practice. The results, where both sphenoid cavities have been thrown into one and their floor simultaneously and properly removed, encourage me to persist along this line.

I am much encouraged with the result of the radical operation on the maxillary sinus and feel that a cure may be expected in most cases. I am still using my modification of taking away the wall of the middle meatus, and frequently follow the method, originally suggested by Jansen, of attacking the ethmoid and sphenoid by the transantral route. Complete ethmoidectomy cannot be done through this approach. It is impossible to handle the anterior ethmoid or supraorbital cells by this technic. However, it has its usefulness in giving enough relief to the three groups—antra, ethmoid and sphenoid—at the one operation, to postpone, sometimes indefinitely, further work on the upper group of sinuses.

I wish to record a refinement that has been most helpful to me. In the ordinary Caldwell-Luc technic the inferior turbinate is not disturbed. As a result, when swollen it interferes with postoperative drainage and even sometimes blocks the opening into the antrum more or less permanently. This fact caused considerable anxiety. Others, including Killian, cut completely through the turbinate, taking out the middle third. This left the anterior and posterior ends of the turbinate intact but was too brutal in its radicality. I find that as much

of the middle of the lower edge of the turbinate as desired can be cut by the use of a small ring punch, working through the antrum and the nasoantral opening. Since using this technic I have been astonished at the freedom from postoperative swelling in the nose. Anxiety as to the permanency of the opening has cleared away. (Fig. 1.)

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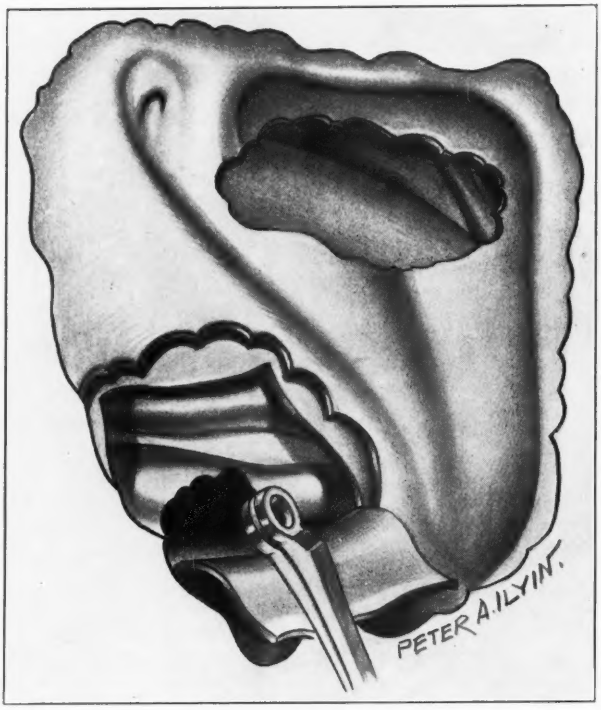

Fig. 1. Represents the nasoantral wall seen from inside the opened antrum. The bony nasoantral wall has been cut away below the attachment of the inferior turbinate extending down to the floor. The inferior turbinate is seen through this opening with the punch forceps biting out its lower edge. The opening through the nasoantral wall in the middle meatus also is shown.

LXXXII.

GENERAL PRINCIPLES OF TREATMENT OF NASAL SINUS INFLAMMATIONS.

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In approaching the general principles for dealing with a mechanism or an organ, one must begin far back, with a comprehensive review of the *mechanism*, of its *constituents* and its own place as a component part of something larger.

The Organism.—As the cell is the ultimate biologic unit of organization, brief consideration must be given it before considering the organism as a whole or any of its constituent mechanisms individually. It must be looked upon as the unit of physiologic activity. Respecting cells one notes certain physical properties—mass, form, elasticity, fluidity, rigidity, opacity; chemical properties,—reducing, oxidizing, hydrolyzing, synthesizing, catalyzing; physiologic characteristics,—supportive, metabolic, reproductive, contractile; morphologic characteristics,—body protoplasm, limiting membrane and nucleus; special classifications,—germinal, somatic, parenchymal, adventitious, fixed, wandering; and varying degrees of special functional activities, with wide limits of indispensabilities. A cell is actually an electric battery, of which certain constituents are electrically negative, others, electrically positive, in the presence of electrolyte; and when stimulated, the cell discharges energy as heat and electricity. Oxygen, carbon and earthy salts combine in protoplasmic molecules; these elements reach the cell from the blood (the plasma and corpuscles of which are essential to cell existence) and are synthesized in cell respiration. Unicellular organisms select nourishment, excrete waste, generate energy and reproduce themselves as self-contained units. With the evolution of polycellular organisms segregation of the work of existence begins; one group of cells subserves discrimination and selection of nutrition; another, dejection of certain excreta; another, mobility; another, physical protection. In this way develops a departmentalized cel-

lular community whose common functions are largely delegated to special groups of cells, each capable of attaining increasing degrees of efficiency because of its exclusive devotion to its own special function. The external layer of cells, exposed to the world, concerns itself largely with adaptations to environmental contacts in discharging its special functional obligations to the cellular community. In time this ectodermal layer evolves relatively higher and higher capacities for special adaptations as the result of increasingly varied environmental contacts and interactions with matter and energies. Coincidentally mesoblastic and entodermal cells evolve capacities for requisite coordinative and cooperative functions essential to community existence. The primitive ectoderm cells subserving protection and sensing require among other things, for their emplacement and support, the rigidity and mass of meso- and ento-derm; subsequent developments come to include selectivity, conduction, secretion, contractility, elasticity, translucence, insulation, tensile strength and a host of further important physical and chemical characteristics in the *evolution of mechanisms* of special function in the service of the cellular community.

Mechanisms.—Thus special mechanisms come to be component parts of the organism, and special cells are the essential constituents of *mechanisms*. The essence of a community organization on this basis is dependence and dependability. Each mechanism is depended upon for something essential by every other mechanism; and each, in turn, depends upon the others for some of its own requirements. The sum total of individual cellular wellbeing is the wellbeing of the whole community—the organism. Obviously there are found in each mechanism constituent cells of varying grades of essentiality. The measure of the efficiency of the body as a whole is the product of all these component factors.

The Cell.—The cell in this connection demands consideration —not per se—but only as it bears upon the wellbeing of the body; the means whereby any cell may bear upon the wellbeing of the whole organism is the individual physiologic mechanism of which that cell is a constituent. The importance of any individual cell depends, therefore, upon its degree of indispensability to its physiologic mechanism. Not only the special

functional capabilities of an individual cell, but the structural details of its emplacement determine its actual serviceability to the organism as a whole. The same cells in their natural emplacements and within a dermoid cyst are not equally useful to the body. Respecting service, it is true concerning cells that "he also serves who only stands and waits." Certain cells are star performers, others are understudies; others, of very low order of functional efficiency. The sole apparent claim to distinction open to some of these cells is that they were the progenitors from which the highly specialized cells have evolved. The more highly specialized, the more quickly the cell wears out or succumbs to injury and the more slowly it regenerates; the less highly specialized, the hardier, and the more quickly it regenerates. Thoroughbreds are less stable than mongrels, nobility are less hardy and prolific than peasant cells. Low order cells live on after death of the body, even for months. They approximate, in this respect, the independent viability of their unicellular prototypes; also, in that they neither depend for much upon others nor warrant being depended upon for much by others; they are in large degree neither givers nor receivers. In youth, cell growth in the aggregate takes place faster than cell wear; at maturity the pace is about even; with senescence, cell growth lags; the individual span of life is determined by the maintenance of sufficient essential cells in physiologic mechanisms to carry on vital functions. As higher cells disappear, their places are taken by lower order cells, of higher individual viability but of lower functional capabilities.

Functions.—Organized functions have to do with maintaining conditions of wellbeing. The complex organism is obviously susceptible of wide variations in its wellbeing. Lowering of serviceability of a single essential mechanism may reduce the index of the entire organism to null in a few minutes, as in drowning, with the obvious possibilities of almost as immediate resumption of the former high level of efficiency with resuscitation. Oxygen, energy, water and food constitute the list of immediate requisites to cellular and organismal wellbeing. The cellular community provides to a certain extent against contingencies respecting the needs for these—the mechanisms of hyperoxygenation make it possible for the pearl

diver to remain under water for six or eight minutes at a time, whereas the mechanism of hibernation permits the bear to go without water and food for months; certain primitive forms of life are capable of existing at —60° and above 212° for considerable periods of time. In contemplating the living organism cognizance must be taken of what evidences there are of far-reaching attempts to provide against destruction. Life, in the raw, is mainly struggle for existence. The phrase, "survival of the fittest," epitomizes the outcome of never-ending encounters with difficulties.

Adaptations.—Successful adaptations have been the only means of individual or generic survivals. Survivors have come to be equipped with the requisite mechanisms for withstanding adversities. Tooth and claw, bone and muscle, hoof and horn, hair and hide, instinct and reason, have come to be what they are because they subserved successful adaptations to adverse environments or conditions; they are *essentials* to the complex organism, the animal body. The boom of the bittern may effectively substitute in the dark, as protective beak, claws and muscle, if it carries certain shades of meaning to predatory prowlers. Sensing is among the first essential functions of the organism; once a mechanism evolves to acquire information suitable motor mechanisms evolve, such as the various defense reflexes; sound production follows hearing, selection follows seeing, revulsion follows smelling, decision follows thinking.

Reactions.—Reactions crystallize out of experiences; in his chairman's address in the Neurologic Section of the California State Medical Association, 1929, Ingham has put it forcefully that "experiences digested by thought form intelligence." With intelligence and experience comes *wisdom.* Reactions underlie, accompany and succeed emotions; gastric muscles contract, initiating hunger; sex hormone pervades the organism, and love comes; the tongue depressor irritating the pharynx produces gagging; with the next sight of the tongue depressor comes apprehension, or fear. Sensations and emotions are close kin. With emotions comes *happiness* or sorrow. Sorrow, wisdom and happiness are examples of intangible byproducts of the operations of material mechanisms. Cocoanuts hang high, but hunger drives and the palm is climbed. Another grabs

for the food and fear or anger results; if fear prevails, it means retreat, hungry and disappointed; if anger drives, the other is repelled, hunger appeased and victory won.

Reaction Patterns.—A successful amour and the lion's roar is in a fair way to modulate on suitable occasion to an imitation of the yearning notes of the mooncalf; his bellicose behavior assumes blandishing enticement. Thus climbing, fighting, lovemaking come into the mechanismal picture as *reaction patterns,* far more extensive than primitive reflexes but fundamentally similar. Misgivings or cowardice and confidence or bravery are byproducts of unsuccessful or successful experiences in applying reaction patterns. Success impels to repeated applications of a reaction pattern, with increasing proficiency; failure leads to death.

Natural Selection.—Jungle growth waxes higher, giraffes with short necks fail in competition with long necked varieties, and in course of time the only giraffe progeny are of the long necked variety. Today's camelopardalis evidences natural selection of certain superior mechanisms. Disputes over leadership or ladies' favors arise among the elk, and are settled face to face; he with the hardest skull survives, albeit with bruises which soon grow calloused; in time the bigger horn becomes the survivor's badge. The tropical sun beats down with actinic violence and pigmented areas suffer least; ultimately brunettes are all the style in the tropics and blondes in the frigid zone.

Summary.—One seems justified in concluding that: (1) Greater mechanismal improvements signify higher and more efficient evolutions—less efficient precursors usually, but not always, suffer regression and obsolescence. (2) The mechanical details of physiologic mechanisms are by no means chance formations; they embody the elements of superior efficiency and have evolved at the cost of a deal of phylogenetic selection and development. (3) Interdependence between mechanisms is extensive and all-important, even though not always obvious. (4) It is safe to accept the comparative superiority of things as they are.

So much for general orientation concerning the organism, its special mechanisms and cells.

It is assumed that the goal of all medical service is optimum health and strength; health and strength are the outcome of

satisfactory adjustments to adverse conditions; adjustments are subserved entirely by physiologic mechanisms, the functionations of which depend upon specialized cells—the more essential the mechanisms, the higher its cellular specializations.

Respiratory Tract.—Now consider the upper respiratory tract as a mechanism, what it does, what measure of value it represents to the body as a whole. It affords advantageous emplacement for the endorgans of smell; it functions as a compound resonator in voice production; it cleanses, warms, humidifies and conducts respired air, to the advantage of the lower respiratory functions and structures. This is the orthodox view respecting it.

To my mind there is much more, of far more vital import to the cellular community, though I have not seen it in text or monograph as part of the nasal function. The sinus is the primary source of nasal secretions; the sinus mucosa is equipped with ciliated columnar cell fields the action of which moves the secretion in one direction only—toward the normal opening. This is reached from the more remote intrasinus areas in not more than approximately 45 to 60 minutes after its appearance on the mucosa. Certain agencies speed up ciliary activities; heat, electric stimulation of the sympathetic, epinephrine, ephedrin and certain carbonates shorten the time for emergence through the normal opening from a given starting point by as much as 50 per cent. Other agencies slow up ciliary activities; electric stimulation of the parasympathetic, cold, pilocarpin and atropin increase the time for emergence through the normal opening from a given starting point by as much as 115 per cent. Dessication and cocainization arrest the movement of secretion entirely, as does sufficient degree of cold. Excessive fluid modifies the extent and direction of ciliary propulsion by introducing the factors of gravity currents; viscosity and surface tension play important parts.

On emerging from the sinus, ciliary fields of the nasal mucosa continue to propel sinus secretion, with occasional additions from glands in the respiratory mucosa, along physiologic pathways; to and fro air currents of nasal respiration aid in this physiologic distribution. The respiratory surfaces of the turbinates receive a film of secretion as the general flow backward along the lateral nasal wall continues, leading ultimately

to the lateral nasopharyngeal wall, where the stream divides, some continuing backward and downward over the posterior pharyngeal wall, some going downward along the faucial pillars and the base of the tongue, ultimately reaching the pyriform sinus regions.

In the course of this journey extraneous matter is taken up from the inspired air, moisture is taken from the saturated expired air and given off to humidify the inspired air, which is also warmed as it passes through the nose. Through the stomata or by intercellular penetration of the mucosa, secretion laden with bacteria, pollen and dust enters the subepithelial lymph lacunæ, making contacts with lymph and integral lymph nodes; through efferent lymphatics contacts are made with regional lymph nodes in the cervical triangles; and eventually the stream reaches the vena cava. The sinus secretion which does not reach this physiologic distribution is swallowed into the gastrointestinal canal, where it mixes with the gastrointestinal contents, again encountering a highly efficient absorption mechanism through the operation of which lymphatic and systemic contacts are also subserved. As the outcome of the contacts mentioned, remote physiologic mechanisms are brought to bear upon the nasal secretions, and vice versa,—nasal secretions are brought to bear upon these physiologic mechanisms. The summation of these endocrine, lymphatic, glandular, hematabolist and other tissue contacts and interactions enters into the determination of individual immunities, resistances, allergies and other general and local pathologies and reactions. This brief allusion to some of the functional activities in which upper respiratory secretions and structures find themselves involved must perforce fail to mention much of importance, but will serve to justify the statement that not only the epithelial cellular functions but also the subepithelial structures and the minutiæ of their disposition and architectural arrangements are important integral parts of one of the vital body mechanisms, and as such are worthy of most respectful treatment and conservation. The nasal organ is indeed a vital organ, and, either in part or as a whole, an indispensable essential to health and strength.

Cellular Replacements.—Studies of cell life seem to establish the following facts: (1) Cells affected by toxins or traumata

possess considerable measure of recoverability with preservation of function, through the processes of readjustment included in the term "reactive inflammation." These processes involve not only self-contained potentialities of the cells themselves but also the interdependent reactions of other remote cell groups included within the general and special mechanisms of resistance and immunity. (2) Some of the highly specialized cells destroyed during processes of inflammatory reaction to intoxication or trauma are not duplicated in the process of healing and repair, their places being taken by cells of lower order and inferior functional capabilities. (3) This substitution for highly specialized cells of those of lower order in a physiologic mechanism results in impairment of function of that mechanism directly proportionate to the extent of such substitution. Not only organic impairments, such as arteriosclerosis and nephritis, but also gradual functional deteriorations incidental to wear and tear or age, are determined by this gradual substitution of cells of lower order for those of higher specialized functionabilities. It is not how long we are going to be able to live but rather how long it is going to take us to die that determines our individual spans of life.

Mechanismal Depreciations.—The biblical "three score and ten years" approximates the average length of time an individual is capable of withstanding the various wearing-out processes among the exigencies of ordinary life. Certain working parts may wear out earlier than others, but in general, by seventy, man is apt to begin to realize in a practical way the meaning of interdependence between the individual subdivisions which go to make up the human body—the nutritional, respiratory, cardiovascular, nervous, glandular, metabolist and various other mechanisms. Excessive rate of deterioration in any one of these systems reflects unfavorably upon the others, not necessarily shortening the entire life span, but degrading the general body efficiency, often for a considerable period of suffering and invalidism prior to the end. He who undertakes the responsibility of directing the welfare of a suffering individual must maintain primarily the attitude of the careful general physician; whatever his ministrations as a specialist may be, they should be guarded against all possible untoward effects upon the general wellbeing of the sufferer.

It sometimes seems that this is lost sight of in the stress of special practice and that this has been the case particularly in dealing with inflammatory sinus diseases. The rhinologist is forced to assume no responsibility for the many bad conditions brought to his office by the sufferers from sinus and other allied nasal troubles, but he has a very definite responsibility to these patients in protecting them from anything which may add to their troubles.

Evaluation of Data.—At times it seems difficult to maintain the orthodox attitude of subservience to bacteriology and roentgenology as they are applied to rhinologic practice in the commoner irritative and inflammatory conditions of the upper respiratory tract. This is particularly noticeable when confronting the not infrequent instances of operative indications based upon X-ray and bacteriologic findings. In considering treatment the data presented by history, general and special physical examination, including X-ray examinations, and bacteriologic studies, should direct decisions. No single factor should prevail. To describe a condition as "streptococcus ethmoiditis" is but another manner of stating that normal mechanisms subserving nasal functions are undergoing disturbance evidenced by misbehavior of local or general nature on the part of tissues; the local and systemic manifestations of what is going on constitute the "clinical picture" of streptococcus ethmoiditis. It is usually taken for granted that the streptococcus is the sole etiology. This I do not feel to be entirely the case, any more than insurrections in Mexico are entirely dependent upon the presence of insurrectos. Pneumococci and streptococci, and Yaquis and insurrectos, are notoriously bad actors, and some are always worse than others; but the mere presence of either does not determine infection or insurrection. The scenery has to be set also, and that involves much else of importance respecting the particular conditions of the country at the time and the degree of unrest among the insurrectos. Much has been learned about the classification of bacteria and conditions altering their virulence; much of value is being worked out with reference to the incidental biochemistry of body tissues as well. A bacterial carrier may maintain freedom from infection for long periods until some profound physical or nerve shock upsets his immunity bal-

ance; whereupon the bacteria begin pathogenic activities. It is known that shock effects profoundly alter biochemical and biophysical tissue conditions, and further, that with convalescence and restoration of former immunities the former biophysical and biochemical conditions are restored. Organisms propagated through certain hosts evidence altered pathogenicity and virulence; and following recovery from infections, tissues manifest increased immunities or susceptibilities; family and racial immunities and susceptibilities are well recognized and significant. One cannot escape the conviction that, in bacteriocellular contacts, the outcome depends upon the infected tissues as well as the infecting organism.

Importance of Tissues.—Tissues occur only as they have been required in the construction of mechanisms; mechanismal evolutions in the face of countless successive and successful struggles with difficulties, their capabilities of self-maintenance, their local and systemic importance as integral parts of the great organism—the human body—suffice to warrant every possible effort to preserve intact each component mechanism in any condition of impaired functionability. Pathologic studies shed light upon the local and general details of cellular and systemic adaptations, the infiltrations, exudations and organizations, the hematabolist, organic, glandular, endocrine and serologic activities, the alterations of biochemic and biophysical conditions, and the metabolic changes, all of which represent mobilizations of the resources of the body to meet emergencies; and we are forced to look upon these resources as highly efficient and usually adequate to the demands of the occasion. They represent not alone the only effective determinants of the outcome of injuries or infections, but also the utmost possible approach to restitutio ad integram in case of recovery, which is a desideratum of inestimable value when contemplating the efficiencies of these same mechanisms throughout a future teeming with similar difficulties. Salvation without benefit of clergy may not offer a strong appeal to the doctor of divinity, and our attitude toward cure without obvious (or should one say "obtrusive") professional aid, might lack certain enthusiasms but as physicians bearing responsibilities to sufferers we need not feel stultified to become partners on the job with natural restorations and tissue repairs. Especially

as, whether we recognize it or not, we become at best only juniors in such a partnership whenever we assume direction of a case. The physics and chemistry of living cell-changes are yielding all too slowly to investigations as to their details. Body chemistry is written largely in colloidal and obscure terms, most of which remain to be translated into intelligible correlation with present day serologic and cellular physiology and pathology.

Chemistry and Physics of Bacterial Penetration.— Many observers during the past decade have verified that the body tends to maintain its normal fixed base concentration—and in many conditions, the fixed base of the blood—irrespective of hydrogen ion concentration; and that high degrees of acidosis or alkalosis actually are found in the presence of normal electrolyte concentration and lead to no serious results. On the other hand, upsets of biochemical balance manifest profound and widely disseminated disturbance of hydrophilia and osmosis, of excreton and secretion, and of intra- and inter-cellular permeability by micro-organismal and inert matter. Increased intercellular permeability may be brought about directly by altering surface tension, which in turn may express lipoid alterations of intercellular lipo-proteids, lecithin, cholesterol, fatty acid and soap particles, in the course of systemic acidosis or alkalosis. Indeed, this conception of the actual mechanics of bacterial penetration has come to be widely accepted. The pregnant suggestion that, among the reactions of resistance and immunity, a reversal of this mechanism tends to arrest further bacterial penetration and facilitate bactericidal tissue reactions in situ, demands attention in connection with any consideration of treatment.

Therapeutic Fundamentals.—The practical details of treatment for any condition must in the very nature of things be worked out in the mind of the individual physician, whether consciously or not, upon the basis of certain fundamental conceptions. The fundamental conceptions must stand upon three legs: the first leg, certain definite ideas of the functional importance, to the mechanism and the general body organism, of the tissues under consideration, and the essential working details of the physiologic mechanism of which these tissues are

a part; the second leg, concrete ideas as to the nature and extent of the affection of these tissues and the urgency of its threat of local or general disability; the third leg, the general tissue reactions and the local processes of repair and resumption of function which may reasonably be counted upon, in the light of past experiences with these tissues under similar conditions. Empiricism is not yet dethroned; it still wields a powerful scepter.

An abrasion of the central portion of the cornea and a similar lesion of the margin may evoke in the physician entirely different reactions respecting treatment. These differences in reactions may determine in the one case the exercise of the utmost delicacy and caution, in the other case of perhaps justifiably casual attention. The reasonable probability of the end-results must be accorded respectful consideration; in tissues which are functionally essential interest or apprehension concerning end-results is bound to be far more keen than in other tissues. Relatively speaking, considerations of local discomfort, of inconvenience or of altered appearance are of much lower order than those of function, yet it frequently occurs that pain or swelling are given far more weight in deciding upon treatment, and ultimate functional impairment far less consideration than they are worthy of. Importunities of the patient should not be allowed to outweigh more important considerations. Treatment should always shape itself to the case under guidance of experience; and experience must take cognizance of ultimate results rather than of immediate ameliorations.

Postoperative Disappointments.—While there may be some differences of opinion regarding the relative efficacy of certain details of treatment, there seems to be very little doubt that many so-called "sinus cases," after undergoing long series of operative and nonoperative rhinologic treatments, find themselves not only no better but very definitely worse. To quote Mosher, at the Spokane meeting of the Pacific Coast Eye and Ear Society, speaking of slight beginning sinus cases: "Gentlemen, you can make them continuous cases, and by operative interference, you can make them permanent cases." One of Mosher's assistants he quotes as saying: "Once a sinus case, always a sinus case." Skillern says, regarding ethmoid

cases: "We have already learned that by applying surgery we have only been cohabiting with chimeras and begetting specters, for who indeed has ever contemplated an ethmoid some months after a so-called complete exenteration, with its conglomerate mass of hypertrophied and scarred mucosa, fibrous tissue and bone, bathed in pus and carpeted with crusts, who has not indeed seen a specter, and a very horrid one at that, particularly if he himself has performed the operation." Perry Goldsmith, in 1925, said: "Recourse to surgery is usually a sad disappointment; for frontal sinusitis attempts to probe or irrigate are likely to do more harm than good"; and quoted, concerning the nonsurgical treatment of nose and throat diseases: "It is better to bear the ills we have than to fly to others we know not of." For many years the writer has been voicing his convictions regarding the necessity of greater care and conservatism in the treatment, especially the surgical treatment, of these cases; it is particularly gratifying to realize that others are showing evidence of similar convictions. Not only in the United States but in Vienna and other continental centers the trend away from radicalism is marked.

Surgical Radicalism.—Bearing in mind what has been said regarding highly specialized cells, it seems obvious that, in conditions jeopardizing the wellbeing of a physiologically essential mechanism (and all physiologic mechanisms are more or less essential), treatment should be calculated to bring about recovery with minimum destruction of functionally essential tissues. Without exception, radical operations devised for inflammatory diseases of the lateral nasal wall tissues are not calculated to bring about any such result. Nor do they take cognizance of possible recoverability of tissues involved in the disease process; on the contrary, they are so designed as to accomplish their actual destruction, together with other essential tissues not even involved in disease process at the time of operation. There is food for much thought and reconsideration of surgical impulses in contemplating what such operations actually accomplish when successfully executed.

Suppuration.—In discussing this question recently with one of the prominent Eastern rhinologists, he said: "But suppose one finds *pus*, not just thick mucus but *actual pus;* he must surely carry his operation to the ultimate source of the

pus." I do not agree with this, if surgical access to the source of the pus involves surgical destruction of normal essential tissues. In the first place, the mere finding of pus does not indicate that it will be there when one looks next time. Suppuration is not permanent—nor even usually of very long duration. It is a natural process of removal of gross quantities of the byproducts of inflammation, which inflammation must be looked upon as a beneficent cellular reaction to undesirable local tissue conditions, such as injuries, intoxications or foreign bodies. During this reaction cellular and bacterial detritus accumulates at various sites in the form of pus; if of sufficient bulk, it finds exit and is recognized as suppuration. Under ordinary circumstances such a natural process proves successful in handling the situation, and with the close of the episode suppuration ceases and quiet is restored with the least possible disadvantage to the individual. Thus the local questions of cellular viability under attack have been decided by the cells themselves, and the wisdom of such a decision transcends the wisdom of the greatest surgeon in the world. In putting the situation in these words the writer does not mean to express disapproval of all surgery under such circumstances. Conservative surgical measures, cooperating with natural tissue reactions, may be of tremendous importance—for example, in venting purulent infiltrations, with perhaps critical relief to the local tissue situation. But no pathologic tenet has ever suggested that instrumentation of infected cells offers any advantage to them in their anti-infectious struggles, or that surgical removal of tissue in process of normal protective reaction to infection should or could terminate the activities of the etiologic factors responsible for the reaction.

Etiologic Factors in Sinusitis.—The late Jonathan Wright has well said: "The shock of bone fracture, the nerve collapse accompanying hemorrhage, even the small shock of a nasal operation, may suffice to open portals to infection, but man or beast does not acquire these infections by having a laboratory practitioner blow into his throat a pure streptococcus culture. One cannot artificially so produce that concatenation of circumstance which forms the practical etiology of Nature." Just what falls within the term "concatenation of circumstance"

is difficult to catalog, but experience forces one to realize that, especially in the category of "sinus cases," the determining factors are not wholly or even chiefly local. And it requires no great amount of self-abnegation on the part of the therapist to accord first place to natural processes of resistance and repair, being content to follow the lead of cellular decisions respecting recoverabilities and functional conservations and to cooperate surgically only if occasion offers.

Importance of Epithelial Tissues.—The rhinologist deals largely with epithelial tissues, whose emplacements are particularly exposed. Infectious, allergenic and other vital enemies of man may all be included for convenience under the term "environment." Environmental contacts all take place through epithelial structures. The outcome of encounters with adverse environmental conditions depends in great measure upon the functional efficiency of the epithelial and subepithelial structures at the contact points. High functional efficiency of these structures requires full normal complement of the highly specialized epithelial and subepithelial cells, in optimum architectural and mechanical disposition and arrangement. It is safe to regard Nature's choice of cells, their emplacements and their mechanical arrangements as the optimum.

Reasons for Postoperative Disappointments.—Much emphasis has been laid upon the surgeon's failure to "clean up" every suppurating cell or to remove the ultimate infected granulation in an infected sinus situation as explaining the continuation of sinus troubles after attempts at thorough operative treatment. The surgeon is often magnanimous in his self-accusation, generously assuming the blame for unsatisfactory postoperative results by attributing them to his own failure to curet or exenterate the remote ramifications of the disease completely. In my own opinion, there is little ground for such an attitude. The subsequent unsatisfactory course of radically operated cases is far more easily explained by comparing the workability of the original model of the mechanism with the unworkability of the man-made modifications of the original model. No great amount of clinical experience or perspicacity is required to realize that, for some reason or other, patients who have been subjected to extensive surgery of the upper respiratory tract are seldom better of their original ills.

It may shock the rhinologist who has not realized that the force Nature utilizes to move sinus secretions is not gravity but the physiologic actions of fields of ciliated columnar epithelium, to suggest that he modify or abandon operations whose sole object is the creation of "bigger and better" drainage openings for sinuses. So all-wise and powerful (and forgiving) is Nature that most of even the latest model "better and bigger" drainage openings undergo gradual postoperative closure, ultimately permitting some measure of resumption of efficient drainage along physiologic lines. Certain man-made improvements on Nature's devices for the wellbeing of the upper respiratory tract present insurmountable difficulties for even Nature's undoing. Among these are turbinectomy, radical curettage and exenteration of mucosa, submucosal structures and accessory nasal cells.

Restitutio ad Integram.—To him who contemplates even the little that we know of the workings of this marvelous organic mechanism with its far-flung co-respondents and its facile and efficient cooperatives in many remote cell groups, it cannot but come with compelling conviction that Nature's scheme, structural details and cellular equipment must be the best. From that conviction it is only a step to the corollary that, when considering what manner of treatment to adopt in dealing with pathologic processes in these regions, restitutio ad integram should be the star to hitch our wagon to, and, as far as possible, only such treatments should be undertaken as shape up to that ideal.

An attempt to codify general principles is, first off, an experience in humility. From a bold start, originating in a sense of exuberant puissance—the effect of glimpsing a few fundamental rights and wrongs—there has resolved a pitiably small residium that might be called "general principles." "The mountain labored and brought forth a mouse." A well known chemical phenomenon ensues only when a few grains of the solute, added to a supersaturated solution, starts the precipitation of a large mass of crystals. The ideas here presented are offered with the high hope that they may enact the part of the few grains, sufficing to precipitate the rich mass of crystallized wisdom from the supersaturated experiences of the listeners.

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DISCUSSION.

DR. E. R. LEWIS (closing): I am in accord with Dr. Mosher concerning the faults and shortcomings in my manner of presenting what I had to say. Concerning the subject matter covered by the symposium, however, I am very pleased; it seems to me timely and valuable. The overwhelming mass of clinical evidence points clearly and compellingly to the necessity of our giving daily practical consideration to what Dr. Proetz stands for, to the proper interpretation of Dr. Kistner's fine pathologic work, and to the fundamentals of surgical and nonsurgical treatments. We must attempt to revise our rhinologic thinking, abandoning localistic narrowness for more comprehensive physiology and therapeusis. My own contribution is another attempt to set forth what I have come to regard as fundamental considerations of supreme importance in determining decisions and directing efforts to help in cases of nasal sinus trouble. Dr. Carmody and Dr. Fenton seem inclined to agree with the trend of ideas advanced in this symposium. Dr. Mosher failed to clarify his own position, and has already left the room, leaving us all in the dark. I am disappointed not to have had more discussion of the general ideas embodied in the symposium, especially from the Pacific Coast members, whose experiences and opinions should in this way be frankly set forth in the transactions.

My failure to get satisfactory results following extensive surgical work on the sinuses gave rise to the first doubts I experienced. Long ago these became so insistent that I began independent studies, seeking for light on the cause of the failures I observed, not only in my own work, but in that of other careful operators. The more I studied the more it was borne in upon my convictions that there was apparent no logical reason to expect increased ability to negotiate infectious and inflammatory difficulties as a result of operative disturbance and destruction of functionally essential nasal tissues. The conservative measures I have been advocating for years were the outcome of this change of rhinologic creed on my part. The matter brought out in this symposium confirms many convictions and compels my further adherence to the line of thinking set forth and the type of rhinologic practice consistent with such thinking.

LXXXIII.

AN EXTENSIVE CASE OF ACUTE OSTEOMYELITIS OF THE FRONTAL AND SUPERIOR MAXILLARY BONES COMPLICATING SINUSITIS, OPERATION, APPARENT RECOVERY, SUDDEN DEATH.*

By Ross Hall Skillern, M. D.,

Philadelphia.

One day shortly before Christmas my secretary came in the rear office and said in an anxious tone that a very sick girl had been brought into the reception room and appeared to be in rather a bad way, so wouldn't I make it a point to see her soon? On going out I saw a young girl (24 years), very tired looking, quite pale, reclining on the sofa, her head bound with a bandage around her forehead. Her parents were with her and both appeared considerably worried. They were immediately invited in, the girl being assisted from the sofa and, with the aid of both her father and mother, was about to reach the inner office, where she almost collapsed into a chair. The father produced two letters, both from physicians in Los Angeles, Cal., who had been treating her, with a history of her case, which was briefly as follows:

During the summer of 1928 she acquired a severe cold, which left her with a persistent cough and a thick yellow expectoration, which was particularly troublesome on arising in the morning. Beginning pulmonary tuberculosis was suspected, and she was advised to go to California for climatic relief. This was done with no apparent change in her condition, and as the nose also appeared affected she consulted a rhinologist.

A diagnosis of purulent maxillary sinusitis on the right side was made, and on August 27th, an intranasal operation consisting of making an opening beneath the inferior turbinate was performed. It was reported that unusual difficulties were

*Read at the annual meeting of the American Laryngological, Rhinological and Otological Society, San Francisco, July 4, 1929.

encountered on account of the denseness of the bone. Two days later (August 29th) she complained of very severe toothache in the upper molars on the operated side, which did not yield to analgesics. At the same time the parts began to swell and soon the canine fossa wall was markedly involved. The patient's condition at this time had become so grave as to necessitate her removal to the hospital. Large doses of morphia (gr. ½) were required to keep her quiet, but even with these the relief was only partial. Several attempts to evacuate the pus were made by lancing through the mouth, but as the bony wall was not penetrated these were failures. Finally, after being in the hospital a week, and, as she stated, about out of her mind with pain, the swelling was again lanced, which was followed by the escape of about one dram of pus (September 10th.)

The pain in the side of face and head, however, was not relieved, and it was necessary to continue the morphin in one-half-grain doses. About this time it was noted that the swelling was slowly creeping up the side of the nose, following the ascending process of the superior maxillary. The condition of the patient now appeared to be steadily going from bad to worse, and on September 17th the swelling at the inner angle of the right orbit was incised down to the bone with no result. After four days this was again lanced; this time about one-half dram of purulent matter escaped but with little relief of general symptoms. During the next three weeks these edematous swellings began to make their appearance at places far removed from the right maxillary sinus; for instance, on September 26th an abscess formed on the right side of the nasal septum, which was opened and evacuated. On October 4th a mass appeared below the right orbit, over the malar bone, which was lanced with no result; however, discharged freely after installation of drainage. Apparent improvement now sets in; at least the acute symptoms subside and the patient is permitted to leave the hospital. (October 20th.) Two days later the right temple began to swell and, after being treated for three more days was finally incised (October 25th), with the evacuation of about one ounce of pus. The infection continued to spread until by November 5th the right forehead, high up almost to the hair line, became involved and began to show

the typical edematous swelling of such ominous significance. At this time active fistulas were discharging at the old places of incision, namely, over the malar bone (incised October 4th), at the inner canthus (incised September 17th) and over the temple (incised October 25th).

Five days later (November 10th) the swelling on the forehead had reached such proportions as to demand opening, which was accordingly done at the hospital, with the evacuation of much pus. This pocket of pus seemed to be in direct communication with the fistula at the inner canthus. From November 10th to the 26th the infection continued to spread until most of the right frontal area was involved, and it was again necessary to open the wound in the forehead, from which escaped a large amount of pus. Examination showed most of the frontal periosteum to be loose from the bone. In the meantime the fistulas in the temple and over the malar had closed and apparently healed; however, swelling was appearing been at the opposite eye (left), showing that the infection had spread over the median line. The patient still complains of pain in the head of intense character. She remained in the hospital until December 12th, during which time the laboratory reports were as follows:

Wassermann report, November 15, 1928, negative.

"X-ray reports, November 13, 1928.—Sinuses: Pathology which appears stereoscopically to be in the anterior wall of the frontal sinus near the midline on both sides; essentially a small foci of destruction surrounded by sclerosis. Small irregularity of the upper borders of the frontal sinus, principally on the left side laterally, where it gives the appearance of erosin. Frontals slightly clouded, giving the appearance of thickened mucosa rather than empyema. Lateral view shows also a definite destructive process in the anterior wall of the frontal sinus, consistent with an osteomyelitis; not radiographically distinctive between pyogenic and tuberculous involvement.

Left antrum shows irregular thickening of wall soft tissues. Right antrum shows general clouding, consistent with secretion; also apparent erosion of its upper border and destructive lesion at its outer angle in the superior axilla and in the adjacent malar bone, consistent with osteomyelitis. Ethmoid re-

gions appear clear. Sphenoid small with hazy borders, suggestive of thickened mucosa."

November 15, 1928.—"Chest: Cardiac silhouette relatively normal in size and outline. Shadows of peribronchial structures somewhat increased in density. Parenchyma of both lungs clear. Findings negative for evidence of present active pulmonary tuberculosis."

Smear, November 16, 1928: Short chain streptococcus found on culture.

Smear, November 20, 1928: Smear shows pus cells and few short chain streptococcus.

Culture, streptococcus. Vaccine, 300,000,000 per cc.

A blood transfusion of 510 cc. of blood was given November 22, 1928.

Diagnosis: Osteomyelitis of malar; superior maxilla and frontal bone.

On December 13th she was brought on to Philadelphia and came under my care on the 19th. Her general appearance was that of a very sick girl, quite emaciated and anemic (lost 30 pounds since August), also so weak as to require assistance in walking. Her head was bound with a bandage, which was stained from the escaping pus. Examination revealed three freely discharging fistulas all on right side. One over left superciliary ridge (Fig. 1), another at the right inner canthus and the third on the forehead high up. The whole upper face and forehead on the right presented a peculiar edematous, colorless appearance, and over certain points was somewhat tender on pressure. The various fistulas were also connected, for it was possible to pass a sound into the inner canthus opening and have it appear through that one in the forehead. Bare and roughened bone could be felt by the end of the probe wherever one tested. Directly above the left frontal sinus palpation reveals an area about the size of one's thumb nail, where the bone is missing, and encircling this spot the bone can be detected, but it crepitates under the finger, not being firmly attached to the surrounding osseous structure. Pressure over this area causes an outflow of pus from the fistula over the sinus. Tenderness is more marked over the left maxillary region. There was also marked edematous swelling under the left eye.

Intranasal Examination.—Considerable secretion on both sides. Right side hyperemic and swollen. Much pus in middle nasal passage. Inferior turbinate swollen and inflamed. Not possible to discover opening into antrum below inferior turbinate. Septum thickened but intact. Recognizing the great value of skiagraphs in this case, she was immediately sent to a roentgenologist, who made the following report:

Frontal Sinuses.—Moderately large. A. P. depth shallow. Bone changes practically occlude the air spaces. Anterior and posterior walls equally diseased and appear to be perforated. In several areas there is a suggestion of a considerable bone softening, which should be looked upon with suspicion as probably exposing the epidural space. The margins of this sinus fade into indistinctness because of extensive bone disease.

Sphenoid Sinuses.—Remarkably clear. Moderately large. Walls clearly definable and show no changes at this date to indicate involvement.

Ethmoid Cell.—Area on both sides shows the blurred, mottled density of disease. The changes indicate reaction of bone to inflammation, osteitis with concomitant bone condensation and areas of bone softening. I believe that many ethmoid cells are completely absorbed, but this appearance seems to maintain largely for the anterior group.

Maxillary Sinuses.—Of average normal size and contour.

Left Antrum.—Diffuse opaque density indicating exudate, possibly some thickening of lining membranes but nothing to suggest polypoid disease. Walls appear to be very clearly intact.

Right Antrum.—Blurred, mottling indicating disease affecting largely the bony walls, in this instance the anterior wall to an extent that there appears to be complete erosion through the anterior wall, but the character of the bone changes are those of "honeycombing."

Summary.—Osteomyelitis involving entire frontal bone, the ethmoid cells, particularly the anterior group and the right antrum, even involving the right zygoma. Walls of the left antrum appear to be intact, but there is evidence of exudate and probable thickened lining membranes. I cannot recognize bone affection at this date. Sphenoid remarkably clear.

The family were notified of the serious condition and the rather remote chances of recovery that even the most radical

operation would offer, but as the girl was rapidly going from bad to worse they decided to give her the only remaining chance and decided to operate at once.

Operation December 30, 1928. Nitrous oxide, oxygen, ether anesthesia. (Fig. 1.) Incision from the outer extremity right eyebrow, through both brows to outer extremity of left. Skin dissected above over large area (almost entire frontal) at upper border of sinuses a mushroom-like mass of gelatinoid pyogenic membrane bathed in thick yellow pus was brought into view as the dissection progressed. (Fig. 2.) A muscle periosteum incision was then made similar to the skin and these structures elevated from the underlying bone which gradually revealed the following condition:

The entire frontal wall, from one end to the other, was a mass of pus, bone sequesters from size of a quarter to that of grains of wheat, degenerated pyogenic membrane and peculiar gelatinoid material. (Fig. 3.) Both frontal sinuses were enormous, the anterior walls of which had apparently melted away, leaving the sinus cavities filled with a soft, friable, thickened grayish black pyogenic membrane, which on pressure exuded great gobs of thick yellow pus. This membrane was entirely loose from the bone and was wiped away with gauze sponges, revealing not only wide but also deep sinuses, the posterior walls of which resembled old worm-eaten wood.

It was at once apparent that any operation here worthy of the name which would offer the slightest hope of even partial success must be ruthless in its execution, with a good chance of the patient succumbing before completion was possible. As death was sure to be the other alternative, this operation was put into instant execution.

First of all, the periosteum was elevated on all sides until a healthy normal bone was uncovered, thus exposing the extreme limits of the diseased bone. (Fig. 3.) Two large strong curettes were then used, Dr. Ridpath on the left and I on the right, and the soft tissues (degenerated mucosa, inflammatory products, etc.) removed, each of us working with the utmost celerity, as the condition of the patient left much to be desired. This was soon removed, which brought to light the condition of the underlying bone, the sight of which made us wonder

whether it was worth while to proceed further. Practically the entire frontal bone was one mass of suppurating bone, crossed and recrossed with tracks and tunnels from which were streaming the products of suppuration.

The disease had burrowed in all directions, leaving here an island of seemingly healthy bone and there a large putrefying sequester. The dura was exposed in four different places, the largest area (about the size of a nickel) being on the left side. (Fig. 3.) The task now to remove all this diseased bone confronted us, which seemed almost hopeless, but with the chisels, gouges and curettes this was finally accomplished (as far as was humanly possible), which left an area as follows: Frontal bone exposed in oval shape 4 inches by 2½ inches. Dura exposed in five places, two of which were exuding cerebrospinal fluid. The large one on the left was pulsating, while bubbles were escaping from the lowest one on the right. (Fig. 4.) Pus was noted coming from the outside edge of the left sinus cavity, which on packing with gauze, to our astonishment, extended for at least two inches into the malar bone. This cavity contained about two ounces of grayish stringy purulent secretion. So much bone had been removed inferiorly that the nasal septum could plainly be seen dividing the nasal chambers.

The patient's condition now began to become alarming. Pulse weak and thready and over 160; respiration shallow and irregular. A hasty survey of the wound was made; a final toilet, then packed with one inch iodoform gauze which, on the right where the bubbles had exuded, was run in over the dura for about two inches. Three sutures were placed at the root of the nose, otherwise cavity left open. The three fistulous openings in the skin, however, were closed with silkworm gut sutures. (Fig. 5.)

Wednesday, December 26th.—Returned from operating room. Pulse 154 and thready. Soon out of ether. Intervenous, saline glucose and digitin, 16 oz. Repeated in six hours. Morp. sulph. gr. ¼, scopolamin.

Thursday, December 27th.—Satisfactory night. Temperature 100.3, pulse 142, respirations 20. Patient good spirits; hungry. T. 102, P. 145. M. S. required.

Friday, December 28th.—Satisfactory night. Complains of general pain in head but mind clear. Pulse and temperature, after a fall to 110 and 99.3, rising; 140 again and 102.3. Noon P. 146, T. 104. Mind very clear; alert. M. S.

Saturday, December 29th.—Restless until 4 a. m.; vomited considerable amount, oz. 8, greenish mucous, three times. T. 103.1, P. 138. Slept four hours. Pulse dropped to 128, T. 102.2. M. S.

Sunday, December 30th.—During night, following intervenous glucose, temperature shot up to 106.0, pulse 150—considerable shock. In four hours down to 98.2, pulse 110.0. General condition greatly improved. Stomach still unretentive but better. Calomel, gr. 1, retained. Wound discharging considerable thin nonoffensive pus from upper fistula. Other closed fistulas still tight.

Monday, December 31st.—General improvement. Stomach more retentive; wound discharging less; closed fistulas still dry. Ate portion of raw apple.

Tuesday, January 1st.—Progressive improvement. Ate ham sandwich, which she seemed to crave, which was retained. T. less than 100.0. P. between 102 and 118. Stitch abscess in nasal fistula. Removed considerable portion of gauze. Ate apple.

Wednesday, January 2nd.—Great improvement. Out of bed for fifteen minutes. Appetite growing. P. 100 to 112. T. 98.3. Wound appears fine, much less discharge. All old packing removed and renewed.

Thursday, January 3rd.—Further improvement in every way.

Friday, January 4th.—Still fairly weak. T. and P. 99.0 and 101.0. Closed outer portions of incisions. Fistulas respectively still draining. Another swelling under left eye.

Saturday, January 5th.—Complains of numbness in left hand. T. higher, P. higher. Not so well. During night left side became paralyzed. Complains of headache on right side. Swelling under left eye large and fluctuating.

Sunday, January 6th.—Condition much worse. Semiconscious, roused with shaking; delirium at times. Pulse and temperature higher. Operation: Opened flap. Some pus in extreme superior part of wound. Removed bone to expose considerable part both frontal lobes. Searched laterally on right

for about three inches. Much gas and many bubbles but no pus. Incised dura (condition now hopeless—coma with rising temperature). (Fig. 6.)

Tuesday, January 8th.—Died.

Autopsy.—Abscess, or, to be more exact, a localized purulent meningitis beneath dura covering fissures of Silvus and Rolando, and extending upward to median line to meet another collection of pus directly over frontal sinuses. About three ounces of thick yellowish purulent material. No signs of meningitis on left. Widespread osteomyelitis on remains of frontal bone, however, only apparent on dural side, external table seemingly normal and healthy.

In Detail.—The gauze packing, when removed from the frontal sinus area, was found comparatively dry. One long strip extended backward from the top of the frontal sinus cavity between the dura and the skull for about an inch, was held in place rather tightly by the swollen tissue. There were two small pockets of pus at the outer angle of each sinus. When the saw perforated the inner table of the skull in the occipital region a thick creamy white pus began to drip from the outer edge. Possibly an ounce of pus escaped before the skull cap could be removed.

After the removal of the skull cap a large extradural abscess was noted 9 cm. in length and 7 cm. in width, in the midline directly over an intradural collection of pus which began about the fissure of Sylvius and extended upward over the frontal lobe in front of the central fissure to the midline of the brain, ending at the intercerebral fissure, covering a space of about 2 inches in length by 4 inches in width, being entirely on the surface of the brain.

This pus was apparently under quite some pressure, as it had caused the formation of a depression on the surface of the brain. The entire side of the brain was deeply congested.

Examination of the Skull Cap Externally.—The dura was absent as high as the frontoparietal suture. The perforating vessels were all injected, giving the external surface of the skull the appearance of being sprinkled with small drops of red paint.

The internal surface showed necrosis and osteomyelitis over an area corresponding to the injected area of the external sur-

face. Upon removal of the brain the greater and lesser wing of the sphenoid showed signs of the infection on the left side. The brain itself was congested and appeared somewhat edematous, although the surface was free from any exudate excepting the abscess area.

When the sphenoids were opened they both contained seropurulent secretion, the lining membrane being quite thick and polypoid. This was most marked on the right side. The posterior ethmoid cells contained an exudate.

Pus and polypoid tissue were present in both maxillary sinuses. Culture, staphylococcus aureus. From the autopsy findings, the infection had become so widespread as to make this case absolutely hopeless.

Laboratory Reports, December 26, 1928.—Wassermann negative (spinal fluid). Pandy's test negative. Infecting organism, staphylococcus albus.

RÉSUMÉ AND CRITICISM.

Experience has shown that these cases of septic osteomyelitis must be classed as inflammatory infections of the bone marrow which spread through the various canals and both break down and liquefy the solid structures without the occurrence of putrefaction. A purulent rarefying ostitis, two varieties, are recognized, one which occurs apparently spontaneously and takes a slow course, showing a tendency to self limitation; the other, known as the diffuse form, which usually follows traumatism, such as operative measures,* and is characterized by its steady and relentless progress, death resulting in from a few weeks to many months.†

The onset is usually rather insidious, beginning with a swelling over the site of the incision which when opened early

* The operation leaves behind an active suppurating focus in contact with the wound. It is more frequent after small than large interventions where the drainage is not sufficient to prevent the infection from spreading.

† Only a few cases of recovery have been reported and all of these were operated upon early in the disease. See McClay, Journ. of Laryng., Oct., 1921; Bulson, Trans. Am. Ac. Oph. and Oto-Laryng., 1925; Mackenzie, Jour. of Laryng., May, 1927; Hastings, Trans. Am. Laryng. Assn., 1927; Shea, Trans. Am. L. R. and O. Soc., 1928.

contains no secretion, but pus soon appears, and when again opened the discharge is profuse. It is also possible to feel roughened bone directly below the swelling, the periosteum being loose. Soon an edematous swelling occurs at some distance from the original focus of infection, because it spreads through the medullary spaces (canals of Breshet) (Fig. 7), which when opened show the same characteristics as the former, and so on ad infinitum.

TREATMENT.

Only the immediate and entire removal of the diseased bone is of any avail, and the resection should be carried wide of the infection. Large areas of bone must be sacrificed, for we have always to bear in mind the bacterial invasion of the Haversian canals, even though microscopically the bone be perfectly normal. Outside of removing the infection another saving feature of this wide resection is the marked tendency toward postoperative reformation of osseous tissue. This is particularly in evidence when the inner table remains intact, although with both tables gone, some reformation occurs if the periosteum still remains in situ.

Fig. 1. Appearance of patient before operation.

Fig. 2. Periosteum exposed. Fistulas larger.

Fig. 3.
Bone exposed. Widespread necrosis. Dura exposed in four areas.

Fig. 4. Appearance of area after curettement.

Fig. 5. Wound partially closed, packed with iodoform gauze.

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Fig. 6. Showing size of dural opening and great congestion of underlying vessels.

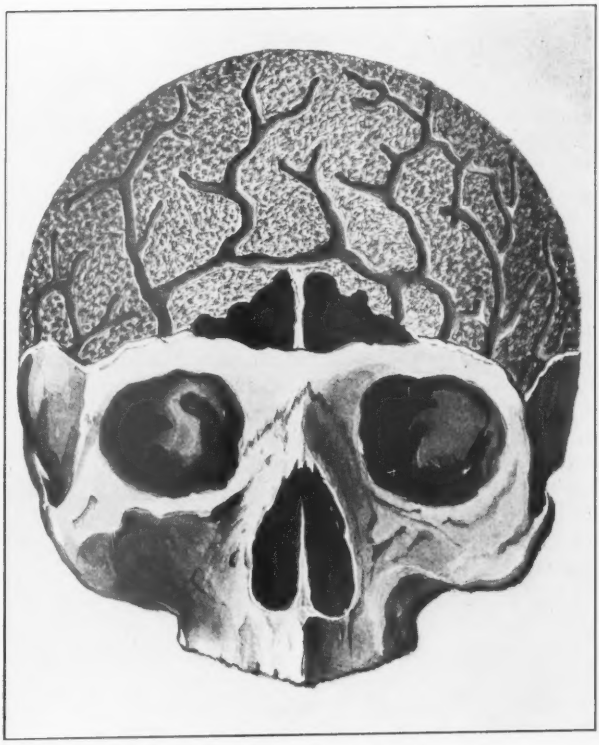

Fig. 7. Canals of Breshet.

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LXXXIV.

THE OCCURRENCE OF TYMPANIC HEMORRHAGE FOLLOWING THE RADICAL OPERATION FOR THE RELIEF OF TRIGEMINAL NEURALGIA.*

By W. J. Gardner, M. D., and James A. Babbitt, M. D.,†

Philadelphia.

Hemorrhage in the middle ear complicating fractures of the base of the skull is a well known entity. That a somewhat similar hemorrhage may occur after certain intracranial operations has not hitherto been recorded. It was first called to the attention of the Neurosurgical Service of the University of Pennsylvania Hospital in January, 1927. A patient (W. Z., File No. 9947), convalescing from an operation for the relief of trigeminal neuralgia, complained of impaired hearing on the side operated upon. Dr. George Fetterolf examined the patient and his report is as follows: "The hearing is below par on the operated side and all the tests indicate that the deafness is of the conduction and not of the perception apparatus. Examination of the ear drum shows that in the middle ear there is a collection of dark blood which fills the lower three-fourths of the tympanic cavity. The pharyngeal end of the eustachian tube is somewhat congested. There is no blood issuing from it."

This discovery subsequently led to an ear study pre- and post-operatively, of the trigeminal neuralgia cases on the Neurosurgical Service. This investigation was carried on by Dr. James A. Babbitt. An analysis of the findings reveals that of a total of 160 cases in which an intracranial operation on the fifth nerve was performed, there was evidence of tympanic hemorrhage in thirteen cases, or 8 per cent. In most of these

*Read before the Medical Society of the State of Pennsylvania, Section on Eye, Ear, Nose and Throat Diseases, held at Erie, Pa., October 3, 1929.

†From the departments of Otolaryngology and Neurosurgery of the University of Pennsylvania Hospital.

cases the hemorrhage seemed to be between the layers of the tympanic membrane, while in others it appeared to be in the tympanic cavity.

In an effort to discover the source of this tympanic hemorrhage we naturally turned our attention to the vascular supply. Anatomists seem to be fairly well in agreement on this point. The following is a description, according to Spalteholtz. (Hand Atlas of Human Anatomy. Spalteholtz, W. Lippincott, Philadelphia. 7th Edition. Vol. II, p. 415.)

1. The superior tympanic artery, a branch of the middle meningeal, enters the superior aperture of the canaliculus tympanicus, traverses that canal to the middle ear and appears upon the promontory.

2. The inferior tympanic artery, a branch of the ascending pharyngeal, enters the inferior aperture of the canaliculus tympanicus to appear on the promontory.

3. The anterior tympanic artery, a branch of the internal maxillary, enters the middle ear through the Glaserian fissure.

4. The posterior tympanic artery, a branch of the stylomastoid, gains access to the middle ear by way of the canaliculus chordæ tympani. The stylomastoid artery, also in its course through the facial canal, sends branches to the mastoid cells and the stapedius muscle, and finally anastomoses at the hiatus fallopii with the superficial petrosal branch of the middle meningeal.

5. The tympanic branch of the internal carotid artery passes through one of the canaliculi caroticotympanici to the mucous membrane of the middle ear.

The veins follow in a general way the course of the arteries.

The principal blood vessels which are sacrificed in the operative approach to the gasserian ganglion are the superficial temporal in the scalp and the middle meningeal in the cranial cavity. As the former has no connection with the middle ear we need not concern ourselves with it. A brief review of the steps of the operative approach to the ganglion will help to indicate the importance and the possibilities of the latter.*

*For details of the operative technic the reader is referred to a recent article—Frazier, C. H., and Gardner, W. J.: "Radical Operation for the Relief of Trigeminal Neuralgia," S. G. & O.; 73-77, July, 1928.

The field of operation is situated immediately in front of the external ear and just above the zygoma. The skin incision consists of a short horizontal arm along the zygoma, which at its posterior end meets a longer curved vertical arm. (Fig. 1.) The superficial temporal artery is severed in making the horizontal arm of the incision. The flap of scalp, as outlined by the incision, is turned forward and sutured to the wound draperies. An incision is then made through the temporal fascia and muscle (Fig. 2), and the flap thus formed is turned backwards and sutured to the draperies. The exposed temporal bone is removed with a rongeur down to the level of the floor of the middle fossa (Fig. 3). With the aid of an electrically lighted retractor the dura is elevated from the floor of the middle fossa until the middle meningeal vessels are exposed as they pass through the foramen spinosum (Fig. 4). With a dental applicator a bit of cotton is forced into the foramen in order to control bleeding, after which the middle meningeal vessels are cut. This permits bloodless retraction of the dura and the exposure of the gasserian ganglion which lies to the mesial side of the foramen spinosum (Fig. 5). In this approach to the gasserian ganglion the dura is elevated from the floor of the middle fossa over an area as shown in the accompanying illustration (Fig. 6). The tegmen tympani and the hiatus fallopii are no doubt frequently exposed, although they are difficult to identify through the small operative exposure. The cotton placed in the foramen spinosum effectively controls bleeding from the middle meningeal artery, but in order to control oozing from the accompanying veins in the dura it is necessary to occlude their lumen also. This is usually accomplished by placing small metallic clips on the dura at the points at which the veins were severed.

It is the anastomosis of the superficial petrosal branches of the middle meningeal vessels with the terminal branches of the stylomastoid artery and vein at the hiatus fallopii that perhaps affords us the best explanation for the problem at hand. As the dura is dissected from the region of the hiatus, this anastomosis must necessarily be broken, and it is fair to assume that in a certain percentage of cases the terminal twig of the stylomastoid artery will retract within the hiatus and

continue to bleed. As this bleeding occurs within the facial canal, there is little to prevent the extravasation from continuing along the canaliculus chordæ tympani to the tympanic cavity, where it will appear as a submucous extravasation. On otoscopic examination this would be visible as an ecchymosis of the tympanic membrane. Also it is possible that the bleeding occurs by diapedesis due to an increased intravenous pressure within the tympanum resulting from the interruption of the venous connections between the middle ear and the middle meningeal veins. This latter explanation was suggested and is favored by Dr. Fetterolf.

These theories, however, do not account for the cases in which there is free blood in the middle ear cavity. In these cases perhaps a simpler explanation will suffice. It is a well known fact that in a certain percentage of skulls the tegmen tympani is represented partly, at least, by a bony dehiscence in which instance the dura is in apposition with the mucous membrane of the middle ear. In the operative approach in such a case the membranous tegmen might easily rupture and allow blood to enter the cavity directly from the middle fossa. In an analysis of our thirteen cases the evidence was in favor of an intramembranous hemorrhage in ten cases, while in the remaining three there appeared to be free blood in the middle ear cavity. In one of the latter cases a fluid level was plainly visible through the ear drum.

That the hemorrhage is usually within the membrane and not within the cavity of the middle ear is suggested by the following facts. On otoscopic examination the appearance varies from a slight ecchymotic staining to a very dark drum membrane. Also the hemorrhagic appearance does not usually affect the entire membrane. The lower quadrants are affected almost twice as often as the upper and the posterior quadrants are affected slightly more often than the anterior. Although there is usually some evidence of conduction deafness in the affected cases, it is not as marked as one would expect if it were due to free fluid in the middle ear cavity. However, this is an unsettled point, as the preponderance of blood stain is in the position which the postoperative decubitus of the patient would tend to locate free intratympanic blood.

Table No. 1 is an analysis of eleven cases which were examined both pre- and post-operatively and in which there was no evidence of hemorrhage. Of these eleven cases there was a postoperative lateralization in the Weber test to the operated side in four cases, or 36 per cent. The tuning fork tests show little change in the range of hearing after operation. This would seem to indicate that the tensor tympani muscle is not a very valuable adjunct to hearing, because the motor fifth nerve, from which it receives innervation, was partially or completely paralyzed in nine of these eleven cases at the time of the postoperative examination.

TABLE No. 1

Average hearing range in eleven cases with no postoperative hemorrhage.

	Normal Side			Affected Side		
Tuning fork	50	200	2000	50	200	2000
Pre-op. (inches)	1.6	7.8	21.	1.3	7.5	21.
Post-op. (inches)	1.3	7.2	22.	1.0	7.8	22.

Weber lateralized to affected side in four cases postoperatively, or 36 per cent.

Table No. 2 is an analysis of seven postoperative cases with evidence of tympanic hemorrhage. Unfortunately, in this series we do not have the preoperative hearing tests for comparison. It will be noticed that the hearing on the affected side is definitely impaired as compared with the normal side. This we must assume is the result of the hemorrhage. However, the Weber test was lateralized to the affected side in only three cases, or 43 per cent. Of the thirteen cases which exhibited a tympanic hemorrhage, only three were subjectively conscious of hearing loss. No treatment was instituted in any of these cases, and those which were observed over a period of months went on to an uncomplicated absorption.

TABLE No. 2

Average hearing range in seven cases with postoperative hemorrhage.

	Normal Side			Affected Side		
Tuning fork	50	200	2000	50	200	2000
Post-op. (inches)	1.6	7.2	17.	1.2	5.0	7.0

Weber lateralized to affected side in three cases, or 43 per cent.

SUMMARY.

1. Tympanic hemorrhage has occurred in 13 of a selected series of 160 cases, or 8 per cent, of intracranial operations on the fifth nerve on the Neuro-Surgical Service of the University of Pennsylvania Hospital.

2. The hemorrhage may consist of an ecchymosis of the drum or of free blood in the tympanic cavity.

3. The vessel probably responsible in the first instance is either the terminal twig of the stylomastoid artery as it emerges from the hiatus fallopii, or the tympanic tributary to the middle meningeal vein.

4. The presence of free blood in the tympanic cavity is perhaps due to the rupture of a membranous tegmen tympani at the time of operation.

5. No treatment is necessary as the blood is spontaneously absorbed.

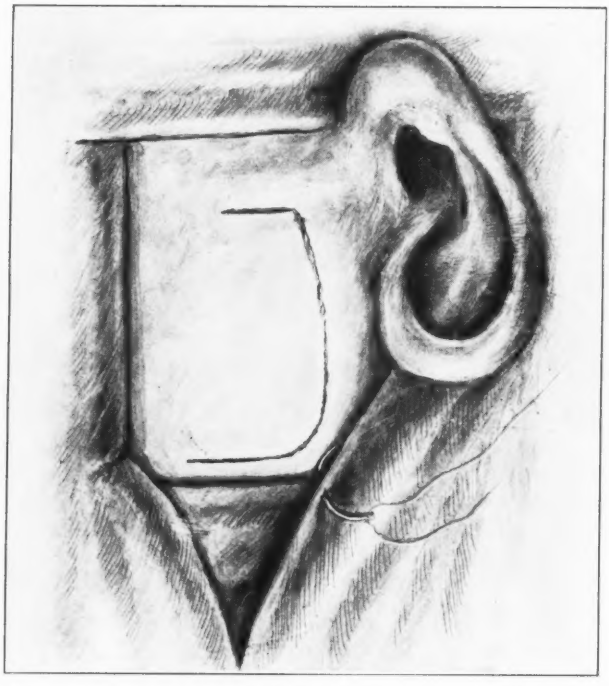

Fig. 1. Location of skin incision with relation to ear. (Right side.)

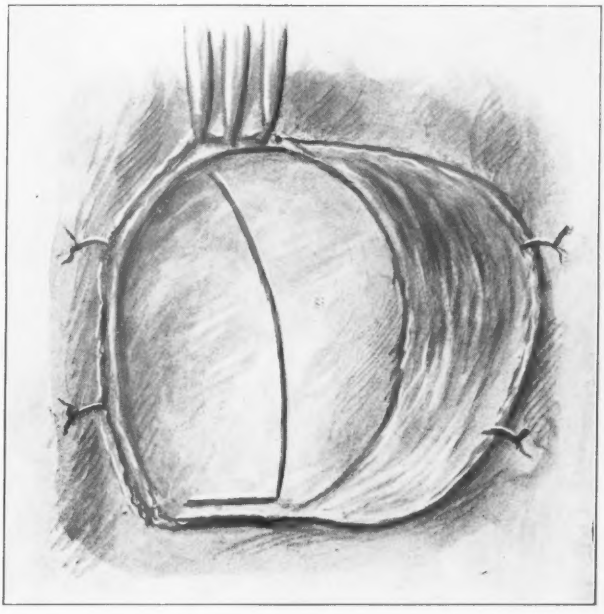

Fig. 2. Cutaneous flap reflected. Line of incision in temporal fascia and muscle. (Right side.)

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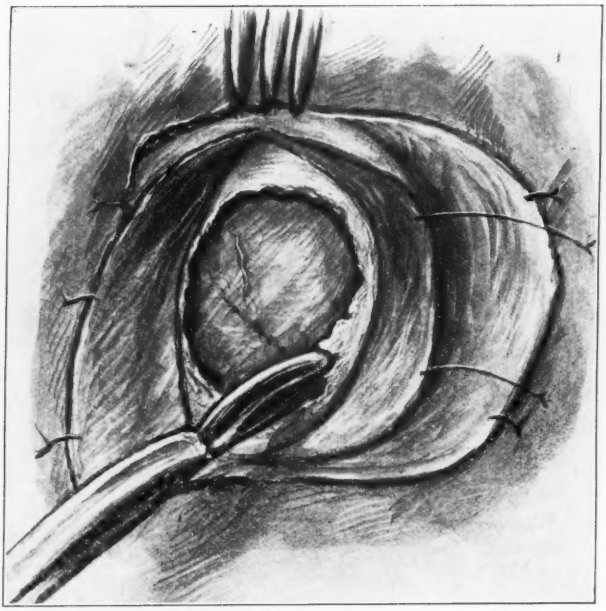

Fig. 3. Muscle flap reflected and sutured to draperies. Dura separated from bone. Bone being removed.

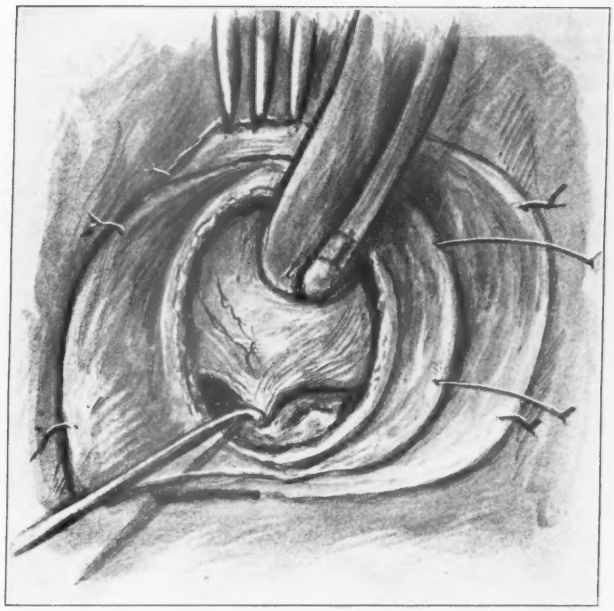

Fig. 4. Foramen spinosum being plugged with cotton to obliterate the middle meningeal artery.

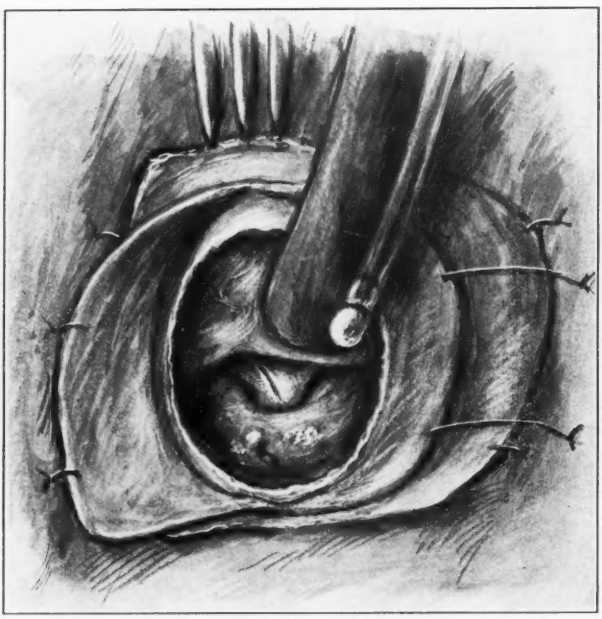

Fig. 5. The third division is exposed and the dura is being separated from the superior surface of the ganglion.

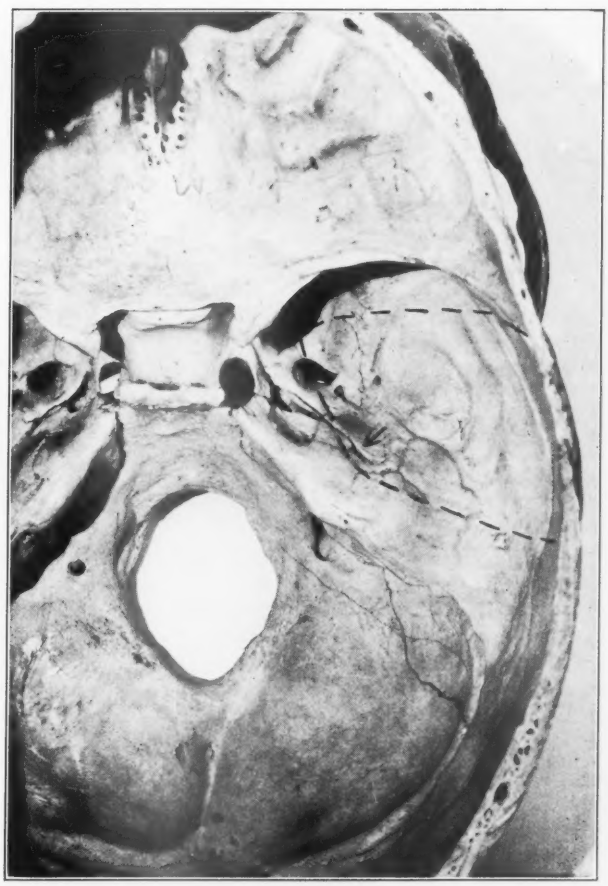

Fig. 6. The dotted line indicates the portion of the floor of the middle fossa from which the dura is stripped in the operative approach to the gasserian ganglion. The arrow indicates the hiatus fallopii.

LXXXV.

IODIZED OIL AS AN AID IN THE DIAGNOSIS OF SINUS DISEASE. (CAMPIODOL-LIPIODOL.)*

By Karl Musser Houser, Ph. B., M. D., M. Sc.,†

Philadelphia.

Year by year the internist and pediatrist look more and more to the rhinologist for aid in the diagnosis of their troublesome cases of headache, asthma, ocular disorders and systemic disease secondary to foci of infection. This growing dependence is not only complimentary to the attainments of the specialist in rhinology but places upon his shoulders the burden of more and more accuracy in the observation, study and diagnosis of the cases referred for his opinion.

In the study of sinus conditions it is necessary to follow certain routine procedures in all cases. A brief enumeration of these procedures would include external examination, intranasal observations to determine the presence or absence of pus, the source of the pus if present, the condition of the mucosa, septum and turbinates, and the presence or absence of polypi. In this study the observer will find the use of one of the various makes of nasopharyngoscopes to be indispensable after the technic of its use has been mastered. Valuable information is often obtained by transillumination of the frontal and maxillary sinuses. Puncture and irrigation of the antra may be indicated. Suction and posture may be used to advantage. Sometimes the bacteriology of the nose and nasopharynx must be determined.

If the above procedures have been faithfully performed, the rhinologist can render an accurate and helpful opinion without further study in about 80 per cent of the routine cases examined. There will be some doubts relative to the exact pathology in the remaining 20 per cent. This portion is then

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referred to the roentgenologist who, if competent, is able to clear up the doubtful points in all but about 5 per cent of the total group being considered. To summarize then, one might say that all sinus cases fall into one of three groups.

1. Those that can be diagnosed accurately by routine procedures.

2. Those that can be diagnosed by routine procedures and the roentgenogram.

3. Those that remain undiagnosed after the above studies have been made. (Approximately 5 per cent.)

Let us then center our interest for the present upon these five patients out of each hundred whose sinus condition is not absolutely determined after the above studies have been made.

In 1922, Sicard and Forestier[1] published their observations on the roentgenographic study of body cavities after the introduction of iodized oil. Proetz,[2] Fraser[3] and MacCready[4] have been the pioneers in the investigation of sinus conditions with the roentgen ray and iodized oil. To Proetz we are indebted for his ingenious displacement method, to be mentioned later. Various other men, who like myself have worked with the method without contributing new features, have from time to time published the reports of their observations.

In the clinic of Dr. George Fetterolf, at the Hospital of the University of Pennsylvania, I have had occasion to study fifty cases by this method. Thirty-five of these cases were examined for the purpose of securing more accurate information concerning one or both maxillary sinuses. Fifteen cases were studied for evidence of pathology of the sphenoid and posterior ethmoid cells. In all but one of these cases the additional information obtained by the procedure gave valuable leads as to the pathology present. In one, the results of the examination led to incorrect conclusions.

The principle of sinus examination by means of the roentgen ray, of course, depends upon the presence or absence of air in the sinus cavity. If it is present it manifests itself as a region less dense than the surrounding tissues and the sinus is reported to be clear. Total absence of air gives rise to the picture of dense clouding and partial absence, hazy variations.

If an opaque substance can be introduced into the sinus cavity, the size of the cavity can accurately be estimated and the condition of its lining be determined.

Our first examinations were made after the introduction of lipiodol, which has an iodin content of 54 per cent, in poppy seed oil. The shadows cast by this preparation were too dense for the best X-ray interpretation, which led to its dilution with an equal part of olive oil, yielding a preparation containing 27 per cent iodin. This dilution has an additional advantage in that the viscosity of the solution is lowered and its introduction into the sinus facilitated. Recently we have been using campiodol with slightly better results.

Campiodol, developed and first used by Frazier and Glazer,[6] contains 40 per cent of iodin bound to the unsaturated hydrogen ions of rapeseed oil. For sinus mapping the best results are secured if half strength is used. For dilution we have used olive oil with satisfactory results. The viscosity of this preparation is still less than the lipiodol preparation and consequently is more easily introduced into the sinuses. Neither lipiodol nor campiodol seem to be in the least irritating to the sinus mucosa, and in none of our cases has any evidence of iodin poisoning developed.

For the maxillary sinus examination one proceeds as in puncture and irrigation. The antrum is first irrigated to remove any blood or pus present in its cavity and to make certain that the point of the needle is in the sinus cavity. The inferior meatus is always used. After irrigation the residual solution is removed by negative suction. If this is not done, a double fluid level will often be obtained. With the patient in the sitting position and leaning slightly forward, iodized oil is then introduced until it appears at the nasal orifice. The patient is then sent to the X-ray department. It is quite possible to perform the injection in the office and send the patient to the roentgenologist, even though he may be some miles away, and still procure good results, although as a general rule it is wise to secure the roentgenogram as soon after injection as possible. The roentgenologist prefers to have but one side injected at one sitting.

When the posterior ethmoid cells and sphenoids are to be studied, the displacement method of Proetz is used. Cocain

in weak solution or 3 per cent ephedrin sulphate is applied to the nasal mucosa until maximum shrinkage has occurred. The patient is then placed upon a table, in a supine position, with the head projecting sufficiently over the edge to allow enough extension to bring the tip of the chin and the external auditory meatus to the same vertical plane. In this position the sphenoid sinus with its ostium is the most dependent portion of the nasal chamber. Five cubic centimeters of the iodized oil are then introduced into the nose. With the tongue of the patient in the K position, suction is applied for short periods of time and repeated ten to fifteen times. The patient remains in this position while being transferred to the roentgenologist. This precaution is probably not always necessary, as the oil usually requires some hours to escape from the sinuses. On several occasions, however, when the patient was allowed to assume the erect position, the oil escaped before films were made.

Dr. Henry K. Pancoast and Dr. Eugene P. Pendergrass of the Department of Roentgenology of the University of Pennsylvania, who have made this study possible by their splendid cooperation, take films in three positions for the maxillary sinuses and four for the sphenoethmoid exposures. For the former the corona-mental, lateral with the head dependent, and Waters position are used; for the latter, frontal, corona-mental, lateral head dependent, and forehead and nose on film.

Without giving the details of case histories, it is perhaps worth while to mention briefly some of the diagnoses established and verified by operation when other methods had failed to demonstrate the pathology. One young man who suffered from frequent attacks of vertigo showed no clinical evidence of sinus disease. Transillumination was negative. The X-ray, however, did show some haziness of the left antrum, but the nature of the pathology was in doubt. Puncture and irrigation of this sinus gave negative findings, as clear fluid was obtained. Roentgen ray studies after lipiodol injection showed a large filling defect. Intranasal surgery was performed, and a large window opened from the inferior meatus into the suspected sinus, which was almost filled with a large mass of gelatinous material so tenacious that it was removed piecemeal with for-

ceps. All vertigo disappeared following this operation and has not returned to date (eight months).

Another young adult male who suffered from gradual loss of eyesight was reported to have a possible right-sided sphenoidal neoplasm. Direct injection of campiodol into the right sphenoid demonstrated nothing more than slight thickening of the mucous membrane. Operation by Dr. Chas. H. Frazier revealed the presence of a suprasellar intracranial tumor. A third male, aged 60, came to our dispensary complaining of pain in the right cheek. This pain had been present for years but had in the past several months become much more intense. Routine studies showed nothing more than some clouding of both maxillary sinuses to both X-ray and transmitted light, probably due to thickened lining. Puncture and irrigation were negative and he was for the time being considered a case of tic doloureaux. Roentgenograms taken after campiodol showed a filling defect in the right antrum, which operation and microscopic study proved to be carcinoma. (See Plates 3 and 4.) By the use of radium and deep X-ray therapy this patient has been made comfortable and the growth has disappeared. If we are ahead of this neoplasm, it is due to early diagnosis.

In one case of persistent headache in a nurse, very large sphenoid sinuses were demonstrated. From the left sphenoid an air cell extended into the septum. (See Plate 8.) In all cases of thickened mucosa and polyposis, the procedure is of value if the diagnosis is uncertain, and in numerous cases valuable information has been secured relative to the sinus situation of asthmatics.

To the present time one error in technic and one error in diagnosis have occurred. Both were maxillary sinus cases. The technical error consisted in causing infraorbital emphysema and the introduction of some iodized oil into the soft parts of the cheek. (See Plate No. 5.) Fortunately, the amount of oil introduced was slight and no ill effects followed.

The diagnostic error was due to the mistaking of a blood clot for a filling defect. This patient, a 35-year-old female, came to the University Hospital complaining of left-sided facial pain. The routine studies showed some evidence of pathology in the left maxillary sinus. Puncture and irrigation

produced no pus, but was followed with profuse bleeding. On account of severe pain she was referred to the neurosurgeon for alcoholic injection of the second division of the left fifth nerve. An attempt was made to perform this injection but no relief was obtained. The injection was followed by profuse nasal hemorrhage. Another maxillary puncture and irrigation washed out large quantities of clotted blood. Campiodol was introduced and a filling defect demonstrated. Operation revealed nothing more than an organized blood clot with some thickening of the sinus mucosa due to a chronic inflammatory condition.

Although certain disadvantages, such as an additional expenditure of time and money upon the part of the patient and the inconvenience of remaining for from 15 to 30 minutes in an uncomfortable position for the preparation of sphenoid and ethmoid films, can be mentioned, it is the feeling of those of us associated in the study of the cases mentioned that sufficient additional information has been gained by the procedure to more than justify the inconvenience and loss of time to both patient and physician. It must be remembered, however, that the procedure should be used only in cases of doubtful diagnosis and that, although an anatomic diagnosis can almost always be secured, pathologic diagnosis frequently will depend upon exploratory surgery and tissue examination.

1826 Pine St.

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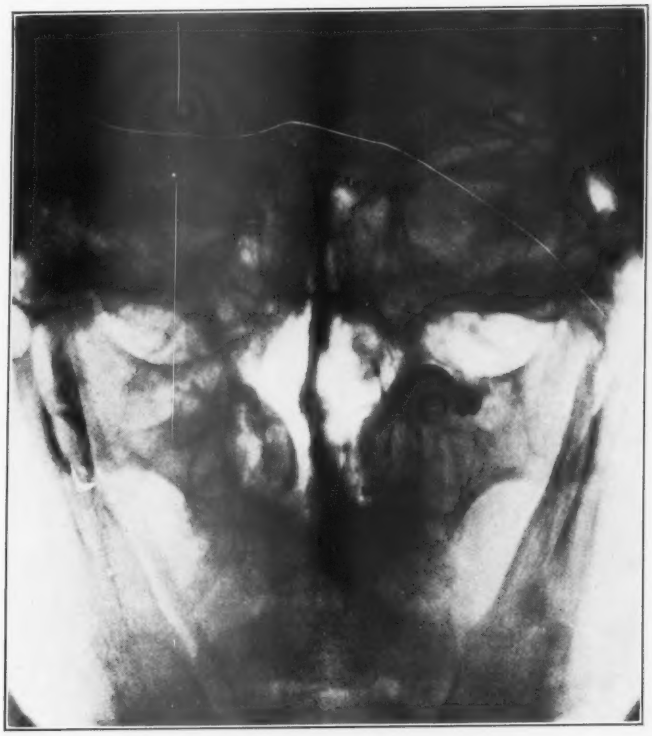

Plate 1. Marked filling defect of maxillary sinus due to thickened mucosa.

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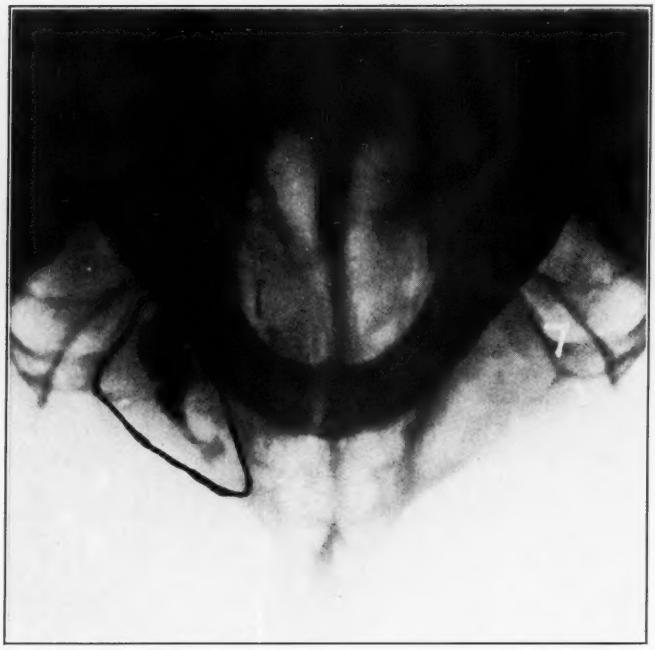

Plate 2. Corono-mental view of Plate 1, showing generalized thickening of mucous membrane. Bony wall reinforced with ink line.

Plate 3. Filling defect in maxillary sinus due to carcinoma of postero-lateral wall.

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Plate 4. Lateral view of Plate 3.

Plate 5. Error in technique. Iodized oil injected into soft tissue of the cheek.

Plate 6. Polyp in maxillary sinus outlined by idized oil.

Plate 7. Iodized oil in sphenoid sinus. Some oil is present in the ethmoid cells and maxillary sinuses. Normal sphenoid mucosa.

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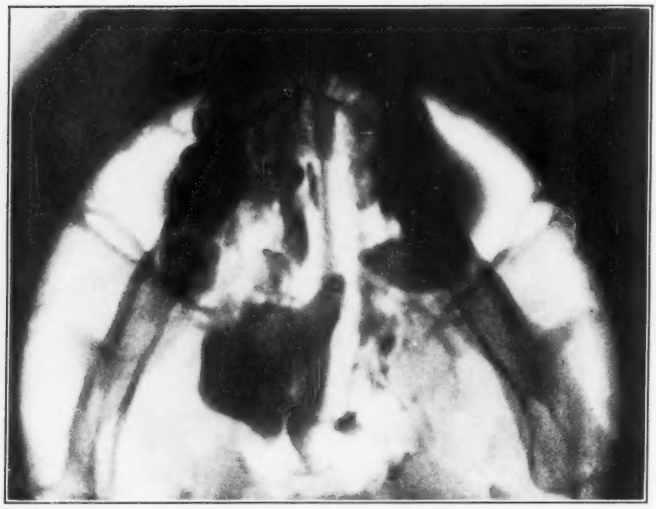

Plate 8. Sphenoid sinus outlined by iodized oil. Note large size and forward extension into the posterior part of the septum.

LXXXVI.

IODIZED RAPESEED OIL (CAMPIODOL) IN THE DIAGNOSIS OF CHRONIC MAXILLARY SINUSITIS.*

By Mark A. Glaser, M. D.; Charles E. Futch, M. D., and Henry Snure, M. D.,

Los Angeles.

The utilization of halogenated oils in certain selected cases of chronic maxillary disease has proved an aid to the more perfect comprehension of the existing pathology. The use of an iodized oil has aided in the determination of pathology which heretofore has been overlooked by the usual roentgenogram and the clinical findings. The addition of an iodized oil to routine rhinoscopy is a valuable adjunct to accuracy in diagnosis, and it is for this purpose we wish to record the use of diluted campiodol for the diagnosis of chronic maxillary sinusitis in forty cases.

The use of an opaque media for sinus diagnosis is not a new one. As early as 1902, Weil and Keinbock utilized freshly precipitated lead sulphate. They called attention to a thickening of the mucous membrane and concluded that variations in this thickening was indicative of the course of the disease. This method did not gain great favor because the preparation was toxic and necessarily had to be washed out of the antrum. In 1921, Hubney suggested the use of barium sulphate suspended in a solution of malted milk. Here again it was necessary to wash out the antrum after taking the roentgenogram. In the same year, Sicard and Forestier introduced lipiodol, an iodized poppy seed oil, for the mapping out of body cavities. This marked the progress of a new era in diagnostic procedures. The value of lipiodol in outlining the sinuses was soon realized and this work was carried out by such men as Reverchon and Worms, 1925; Fraser, 1926; McKelvie, 1926;

*Read before the Los Angeles County Radiological Society, March 20, 1929.

MacCready, 1926; Goodyear, 1926; Anderson, 1928; Trible, 1928, etc. Fraser diluted lipiodol with paraffin, or olive oil, until a 14 per cent iodin content was obtained; his results were satisfactory. McKelvie first attempted the use of sodium iodid, but soon found it was unsatisfactory because it absorbed through the cotton used in plugging the puncture, or the meatus opening, thus giving a distorted shadow. He, however, obtained satisfactory results with lipiodol. MacCready utilized potassium iodid, but because of unsatisfactory results, applied iodipin 10 per cent.

Due to some of the disadvantages of the pre-existing iodized oils, particularly when applied to the central nervous system, Frazier and Glaser reviewed the subject of opaque substances and, with the aid of Dr. George Raiziss, synthesized a new compound, iodized rapeseed oil, which we have utilized in the outlining of the maxillary sinuses.

Experimental work was first directed to the various elements in order to determine which of these would prove the least toxic and at the same time cast sufficient shadow to be of clinical value. In all, some thirteen elements were investigated —barium, bismuth, bromin, silicon, tungsten, strontium, lead, iron, copper, silver, gold, platinum and iodin.

In order to discard those elements which cast insufficient shadow, the following technic was devised: A saturated solution of the most soluble salts of the compound was made up in distilled water and the radiographic opacity compared with 5 per cent solution of sodium iodid. If the shadow casting property was less than sodium iodid, the solution was discarded; if equal or greater, the solution was tested for toxicity by cisternal injection into the subarachnoid space of dogs. In this manner those compounds of high toxicity and poor shadow casting ability were rapidly eliminated. It soon was conclusively shown that iodin was the element of choice, particularly because of its low toxicity and great solubility. The next step was to determine which of the iodin compounds would prove the more satisfactory. Various compounds of iodin, such as iodids, iodates, periodates, iodophenophthaleins, iodized fluoresceins and iodized oleic, benzoic, quinolin, thymol and protein compounds were then experimentally considered. Many

of these proved unsatisfactory because of their insolubility, which naturally reduced their shadow casting properties, while others were toxic upon cisternal injection. It was for this reason our attention was directed to iodized oils. Our selection of oils for iodization depended upon low viscosity, nonirritability, high iodin value and low hydrogenion concentration. Cod liver oil, menhaden oil and sweet almond oil were selected. The resulting products proved irritating or too viscous and were discarded. Rapeseed oil, a vegetable oil, obtained from Brassica napus, Brassica campetris and Brassica rapa, which belong to the family of Cruciferas, also known as colza oil, was then iodized. It is composed of the glycerides of stearic, erucic and oleic acids. It is employed as an edible oil and for various industrial purposes. Its specific gravity is about 0.914. The saponification value ranges from 167 to 168 and the iodin value 93.5 to 105.6; its viscosity is 250 at 100 degrees Fahrenheit. Upon iodization a light yellowish product is obtained with a specific gravity of 1.289 and an iodin content of 43 to 45 per cent. It deteriorates very slowly when exposed to light or heat; upon radiographic exposure an intense shadow is obtained, so much so that dilution products may readily be made without destroying its clinical value.

Campiodol is an oil of very low toxicity. Given by mouth, dogs have withstood 6.75 cc. per kilogram of body weight without toxic effects. Injected into the internal carotid artery with ligation of the external carotid, the dogs were able to withstand 1.5 cc. per kilogram of body weight. Six cc. of oil have been injected into the subarachnoid space by cisternal injection in dogs weighing from 4 to 5 kilograms, without toxic effects. Spinal fluid cell counts on dogs where in 2 cc. of the iodized oil have been injected by cisternal puncture varied from 250 to 600 cells per cubic cm. between the first and second day. At the end of five or six days, the cell count ranged between 5 and 15 cells per cubic cm. These dogs have remained alive in the laboratory kennels for a period of six months after injection, showing no disturbances in any way. The oil was always freely movable and never encapsulated. In clinical cases of hydrocephalus 7 cc. of the oil were injected into the ventricles with a maximum count of 310 cells per cubic cm. on the second day.

Emulsified campiodol used in pyelography clearly demonstrated the inertness of the product. As high as 125 cc. of the emulsified product was utilized in a patient with hydroureter and hydronephrosis without pain or toxic effects (Glaser and Kutzmann).

It may readily be noted that campiodol is an oil of extremely low irritating qualities and may be used with safety in the maxillary sinus.

In order to properly dilute campiodol, experimentation was carried out with such diluting agents as liquid petrolatum, olive oil, pure rapeseed oil and finally ethyl olive oil. It was found that liquid petrolatum was irritating; olive oil greatly increased the toxicity; while pure rapeseed oil gave a product with a viscosity slightly greater than could be obtained with ethyl olive oil.

The straight iodized rapeseed oil is recommended for bronchography (Glaser, Brunn and Faulkner). A four-to-one mixture is recommended for use in the subarachnoid space to determine spinal block; for arterial use (Frazier and Glaser), for the outlining of fistula and in the female genitalia. The emulsion with acacia is recommended for use as a pyelographic media because of its low viscosity and miscibility with urine in the kidney pelvis (Glaser and Kutzmann). For sinus work, which we are considering in this paper, 50 per cent dilution has proven the most satisfactory. The low viscosity enables the oil to be injected without special syringes and also allows a shift of the oil in the sinuses, thus enabling the outline of the sinus walls. Due to its diminished shadow-casting properties, the essential soft tissue details which we must clearly outline are not obscured by a dense opacity. We have utilized this oil in forty cases with excellent results, namely, in the ease of injection, the definition of details and the lack of toxicity.

The maxillary sinus has various forms of pathology which must be accurately ascertained. The presence of pus, with or without thickening of the mucosa, chronic maxillary sinusitis with great thickening of the walls, or polypoid formation, dentigerous cysts, sarcoma, mucocele, etc., are among the more common pathologic entities. In addition, there are abnormalities of the normal sinus, such as thickening of the wall, or un-

developed sinuses. In the young, before the sinuses are properly developed, the detail may be blurred by unerupted teeth, and in adults the density of the bone may be increased to such an extent as to be misinterpreted as sinus disease.

Scheir in 1897 was the first to diagnose pus in the nasal sinus by radiography and confirmed this diagnosis by irrigation. This was followed by the work of Killian, Pfahler, Coakley, Caldwell, Chisholm and Mosher. They established the fundamentals in the diagnosis of chronic maxillary sinusitis and concluded that a cloudy sinus upon the X-ray film was caused by the accumulation of fluid, which was free or fixed in the thickened mucosa. This was a very important diagnostic step, and it then appeared every case of chronic maxillary sinusitis could be diagnosed by the cloudiness of the antral region in the roentgenogram. This diagnostic evidence soon proved inaccurate. Cases with the presence of pus were reported with negative X-ray findings (Holmes, Ruggles, Lilly, Johnson); conversely, cases without pus showed a cloudy sinus (Lilly, Albrecht, Johnson, Turner).

Clinical examinations, such as puncture and irrigation, frequently fail to show pus, even though it is present. In these cases the sinus may have emptied itself immediately before examination, the contents of the sinus may be so viscous they cannot be aspirated, or there may be a mechanical obstruction of the ostium of the sinus, such as a polyp or hyperplastic middle turbinate. In these cases, where the presence of pus is questionable, the use of campiodol may frequently solve the problem.

Repeated attacks of inflammation in the nose and the extension of this inflammation into the sinuses give rise to an edema of the mucosa and cystic degeneration of the glands. After the inflammatory signs have disappeared from the nose, pus may remain in the antrum due to its dependent position. If the antral infection rapidly subsides, the mucous membrane returns to normal. If the antral infection exists for a long period, the mucous membrane becomes thickened, there is a round cell infiltration and the formation of deep seated microscopic abscesses.

To determine the presence or absence of pus is insufficient data. It is very important to estimate the thickness of the

antral mucosa. This can readily be accomplished by the use of campiodol. In some of these cases the mucous membrane will be normal or slightly thickened, and the patient may go on to recovery by medical treatment (case 1); whereas, in other cases the mucous membrane will be so markedly thickened that operative procedure will be necessary (case 2).

Case 1.—M. C. W., male, age 40 years.

Complaint: Tenderness of the right maxillary region and right nasal discharge of six weeks' duration.

Primary roentgenogram: Slight cloudiness of the right antrum.

Clinical study: The right antrum was irrigated and a moderate amount of foul granular pus was present in the returned fluid. Six cc. campiodol was injected without removing the trocar.

Secondary roentgenogram: The right antrum was well filled with opaque media and the mucous membrane showed a thickness of about 2 mm. There was a slight irregularity at the orbital angle (Fig. 1).

Treatment: Even though foul granular pus appeared in the washings, X-ray with campiodol demonstrated a 2 mm. thickening of the mucous membrane. Conservative treatment was indicated and carried to a successful issue.

Case 2.—B. M., male, age 20 years.

Complaint: Right nasal discharge for a period of two years.

Primary roentgenogram: Cloudiness of the antra.

Clinical study: A trocar was introduced through the inferior meatus and the right antrum irrigated. The returned fluid showed the presence of foul granular exudate. Five cc. campiodol was injected without removing the trocar. The left antrum was irrigated and a small amount of mucopus returned in the washing. Seven cc. campiodol was injected into the right antrum.

Secondary roentgenogram: The mucosa of the right antrum was 8 mm. thick and the mucosa of the left antrum was 3 mm. thick (Fig. 2).

Treatment: With the clinical findings and X-ray report as above, a radical procedure was indicated in the right antrum and conservative treatment in the left. A Caldwell-Luc operation of the right antrum demonstrated a chronic suppurative

sinusitis (Fig. 3). The left antrum was treated by irrigation. The patient made an uneventful recovery.

When the mucous membrane becomes greatly thickened, polyps are formed, myxomatous degeneration occurs and occasionally even an osteitis is present. These severe cases of chronic maxillary sinusitis are usually diagnosed by cloudy appearance of the antral region upon the X-ray film. Here again X-ray, as well as clinical observations, will frequently fail in the diagnosis. By the use of an iodized oil, the exact thickness of the antral mucosa can be determined. If the wall is thickened to 2 or 3 mm., conservative treatment is indicated (Fraser). Case 3 demonstrates very clearly the value in determining the exact degree of mucosal thickening.

Case 3.—V. O., female, age 32 years.

Complaint: Bilateral nasal discharge of eighteen months' duration and intermittent tenderness of both maxillary regions.

Primary roentgenogram: Cloudiness of both antra.

Clinical study: Irrigation of each antrum showed moderate amount of mucopus in the returned fluid. Bilateral injection of 5 cc. of campiodol was accomplished without removing the trocar.

Secondary roentgenogram: The mucous membrane was thickened from 4 to 6 mm. in each antrum. The right side was more irregular and thicker than the left (Fig. 4).

Treatment: With these clinical and roentgenologic findings a bilateral Caldwell-Luc procedure was indicated. Upon opertion of the right side an 8 mm. thickened mucosa was revealed. The left side is to be operated upon at a later date.

When the mucous membrane becomes excessively thickened and polyps are formed, accurate diagnosis is extremely difficult. It is the belief of some roentgenologists that polyps can be diagnosed in all cases, while others feel they can diagnose them in most cases (Dea), and still others concede the diagnosis of polyps is by no means a certainty (Snure).

Waters and Baldron report a case wherein both clinical and roentgenologic signs were negative, yet operation revealed the presence of a polypoid growth. Dea reports two cases of normally thickened maxillary bone diagnosed as polyps. The differentiation of polyps and mucoceles also offers difficulties.

Waters and Doub state that the polyps have an inflammatory reaction which is designated by an even cloudiness in the antral area on the film. Choanal polyps arise from the thickened membrane of chronic maxillary sinusitis, squeezing through the ostium, and are not readily differentiated from the true choanal polyp.

The use of an iodized oil will greatly aid in the accurate diagnosis of polyps, will differentiate polyps from mucoceles and a normal thickened maxillary bone, as well as differentiate the true choanal polyps from the choanal polyps arising from chronic maxillary sinusitis. If the mucous membrane is excessively thickened better shadows can be obtained by the use of full strength campiodol.

Case 4 demonstrates the value of campiodol in a dignosis of polyps. This was verified at operation. This case also showed the value of the iodized oil in determining the thickness of the mucous membrane. In the left antrum conservative treatment was indicated.

Case 4.—R. F., male, age 41 years.

Complaint: Continuous right nasal discharge of three years' duration and intermittent left nasal discharge.

Primary roentgenogram: There was a cloudiness of both antra with a suggestive polyp in the left antronasal wall.

Clinical study: A trocar was introduced through the inferior meatus and washings from the right antrum showed granular pus in the returned fluid and from the left antrum mucopus. Campiodol was injected in each antrum.

Secondary roentgenogram: Each of the antra were filled with campiodol. There was a constant deformity of shadow in each antra, the mucous membrane of the right was 4 mm. thick with a polyp in the antronasal wall. The mucous membrane of the left antrum was 3 mm. thick (Fig. 5).

Treatment: A Caldwell-Luc operation was performed on the right maxillary sinus. The mucous membrane, which was thickened to about 4 mm., was removed. A large polyp was found in the superior nasal angle (Fig. 6). The patient had clinically shown discharge from the ethmoid cells, and for this reason a complete exenteration of these cells was accomplished from the antral approach. The left antrum was treated conservatively. The patient made an uneventful recovery.

Cysts of the maxillary sinus are usually single and arise from the floor of the antrum. They are frequently associated with abscessed teeth. X-ray alone may differentiate them. Sarcoma of the antrum usually gives an even cloudiness. Campiodol again is of great value in the differentiation of these conditions. Case 5 shows the presence of a cyst which, however, was diagnosed without the aid of campiodol. In this case the thickness of the wall was determined, and in spite of the cyst the right side was treated conservatively. The left side had definite polypoid formation as well as a thickened wall and was operated upon.

Case 5.—H. S., male, age 38 years.

Complaint: Bilateral nasal discharge and intermittent maxillary tenderness.

Past history: The patient has had symptoms for two years. A right sided cyst was diagnosed at this time, but no thickened membrane was demonstrated. One year ago the left antrum gave symptoms, and a radical Caldwell-Luc was carried out in another clinic.

Primary roentgenogram: Both antra were cloudy and the right antrum presented an opacity on the floor which was interpreted as a cyst.

Clinical study: Both antra contained foul granular pus upon washing. Campiodol was then injected.

Secondary roentgenogram: The mucous membrane of the left antrum was 8 mm. thick. Recurrent polyps were present. The mucous membrane of the right antrum was 3 mm. thick. There was a cyst on the floor (Fig. 7).

Treatment: A radical Caldwell-Luc was again performed on the left side with the removal of polyps and thickened membrane. The right side was treated conservatively but the cyst remained. At present there is no recurrence of symptoms.

Technic of Injection.—The sinus is approached more easily for injection through the inferior meatus with a Coakley antrum trocar. Anesthesia is started with butyn-ephedrin solution, and after the region becomes shrunken and anesthetized 10 per cent cocain adrenalin is applied to the exact region of puncture, namely, the angle of attachment of the inferior turbinate to the nasal wall of the antrum.

The sinus is irrigated with a warm saline solution and the type of discharge noted in the returned fluid. Following irrigation, the sinus is dried by pumping air through the trocar. The head is tilted from the affected side to enable all of the solution to run out through the natural opening. The irrigation bulb is then removed from the trocar and a 10 cc. Record syringe with a three-inch rubber tubing is attached. The head is then tilted towards the affected side and the sinus is filled with a 50 per cent campiodol. The usual amount injected in a sinus varies from 5 to 7 cc. The injection is not complete until oil appears at the external nares on the injected side.

The thickened edematous membranes often occlude the puncture opening caused by the injecting needle so the campiodol may remain several weeks within the antrum. No deleterious results have been observed from this retention.

Roentgenologic Technic.—While all of the various sinus positions are useful, the best results were obtained with the prone Waters, prone Granger, supine and prone lateral views. Stereo films in Waters or supine lateral position help to determine the thickness of the membrane. As a written description of technic is sometimes confusing, we are including photographs of the positions used with reproductions of X-ray films obtained in each position. If both antra are injected at the same time, the X-ray is directed obliquely. Better results are obtained by raying each antrum separately. If the nasal passages are packed with wet wool, the patients can often be sent several blocks to an X-ray laboratory. Better films are obtained if the injection is followed by immediate roentgenogram.

CONCLUSIONS.

1. Campiodol, 50 per cent, is a stable, nontoxic, free-flowing oil, satisfactory for antral mapping.
2. The use of campiodol permits a more definite diagnosis of chronic maxillary sinusitis and in no way inconveniences the patient.
3. The use of campiodol permits a more definite decision as to surgical or medical treatment.
4. The use of campiodol excludes errors due to anatomic abnormalities.

5. The use of diluted campiodol, a free flowing oil, in conjunction with the described roentgenographic technic insures complete filling of the maxillary sinus and thus accurately visualizes the thickness of the mucosa.

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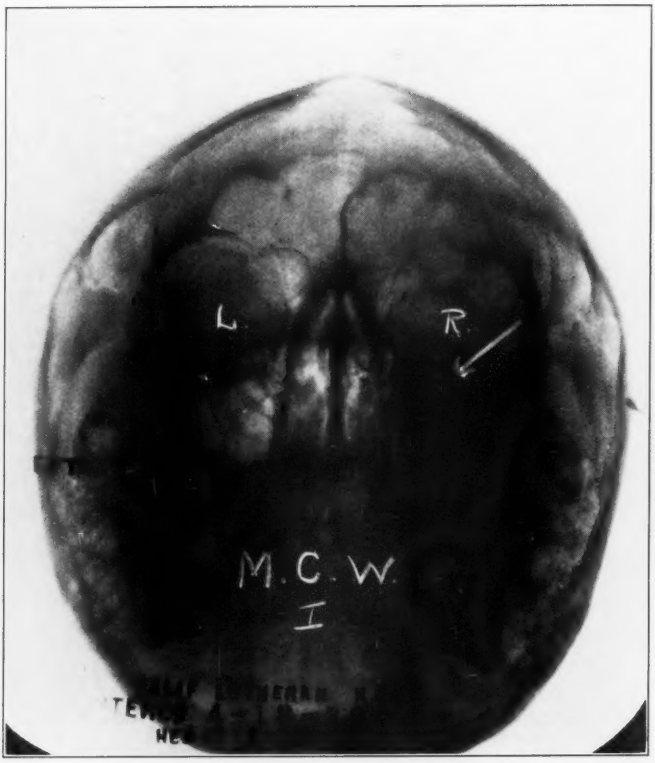

Fig. I. Case 1. The right antrum is well filled with opaque media. The mucous membrane is thickened about 2 mm. Note the slight irregularity at the orbital angle.

Fig. II. Case 2. Campiodol injection of both antra shows the wall of the right antrum thickened to about 8 mm. and the wall of the left antrum to be about 3 mm.

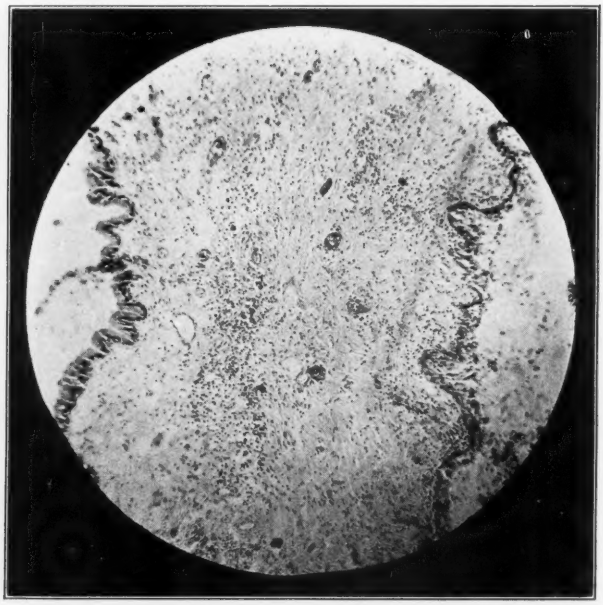

Fig. III. Case 2. Photomicrograph of tissue removed at operation. The surface of the mucous membrane is covered with pseudo-stratified epithelium. The dense submucosa is infiltrated with many round cells and large mononuclears. Diagnosis: Chronic suppurative maxillary sinusitis.

Fig. IV. Case 3. Mucous membrane is thickened from 4 to 6 mm. in each antrum. The mucous membrane of the right side is more irregular and slightly thicker than the left.

Fig. V. Case 4. The mucous membrane of the right antrum is 4 mm. thick with a polyp in the antronasal wall. The mucous membrane of the left antrum is about 3 mm. thick.

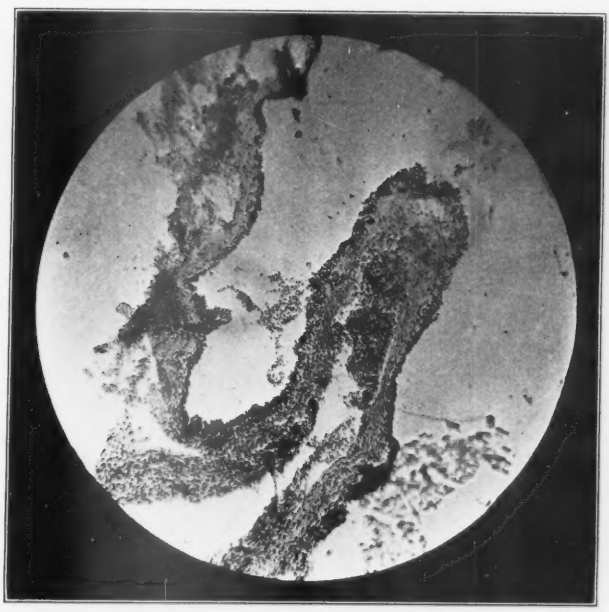

Fig. VI. Case 4. Photomicrograph of tissue removed at operation. The surface is covered with pseudo-stratified epithelium. There is a definite polyp which shows myxomatous degeneration and granulation tissue. There is a diffuse round celled infiltration. Diagnosis: Chronic polypoid maxillary sinusitis.

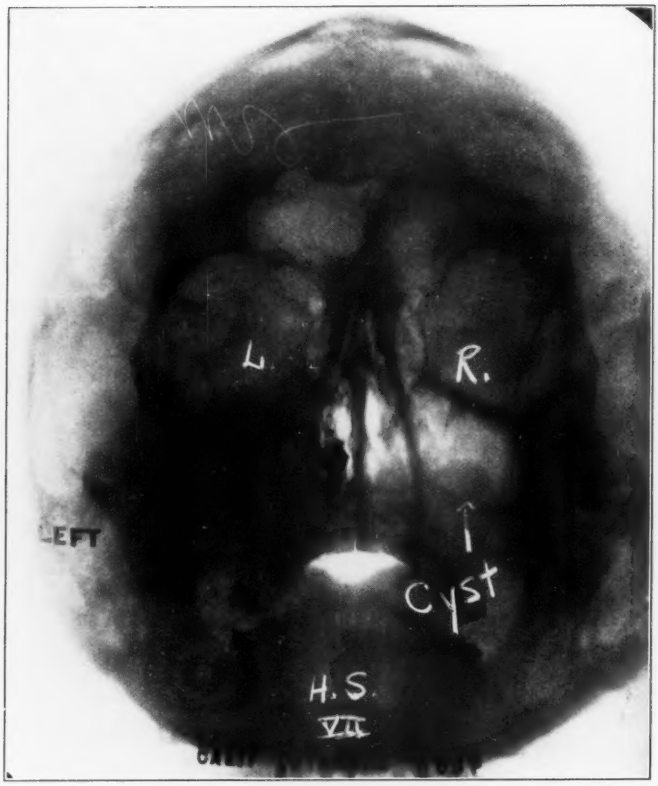

Fig. VII. Case 5. Campiodol injection of the left antrum. The mucous membrane was definitely thickened and polyps were present. There is a cyst in the floor of the right antrum.

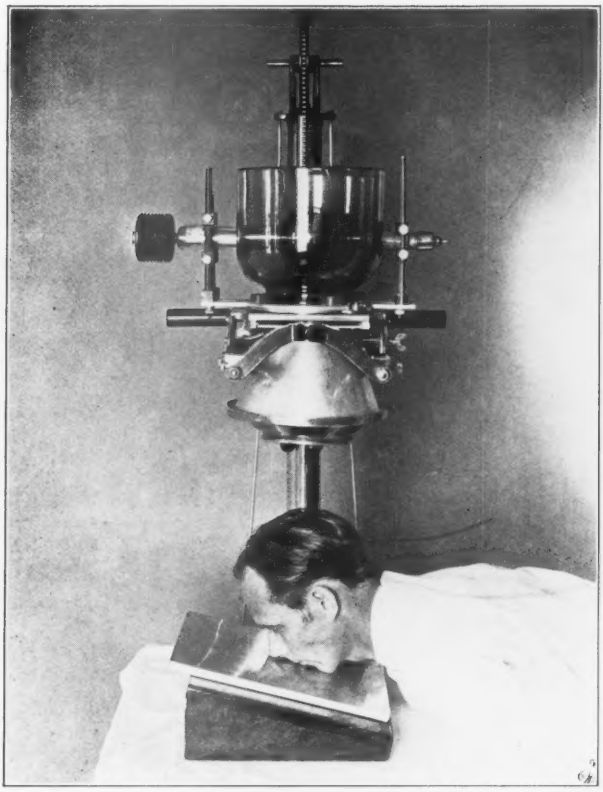

Fig. VIII. Stereoscopic prone Waters' position is used to indicate the degree of mural thickening. Fig. IX shows the film obtained in this position.

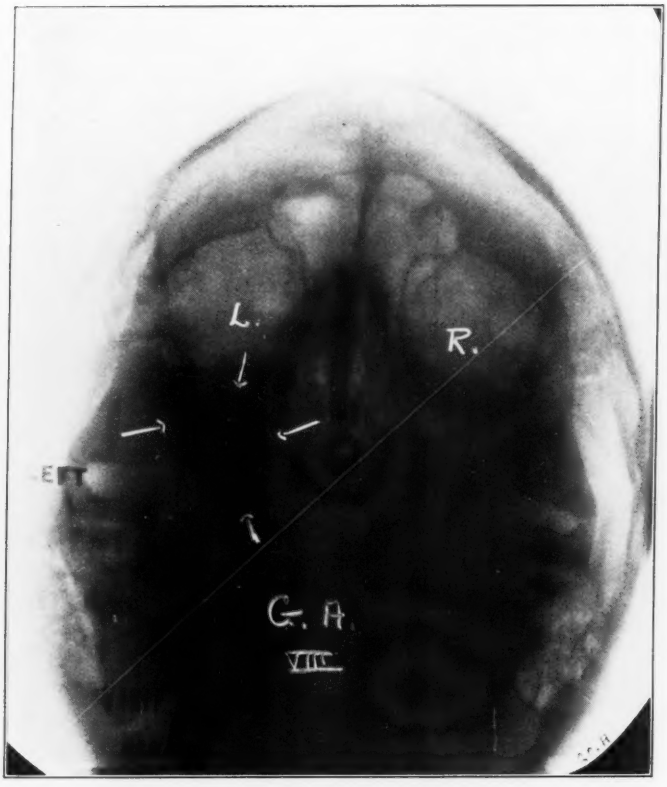

Fig. IX. Film obtained in prone Waters' position. Note the thickness of the mucous membrane.

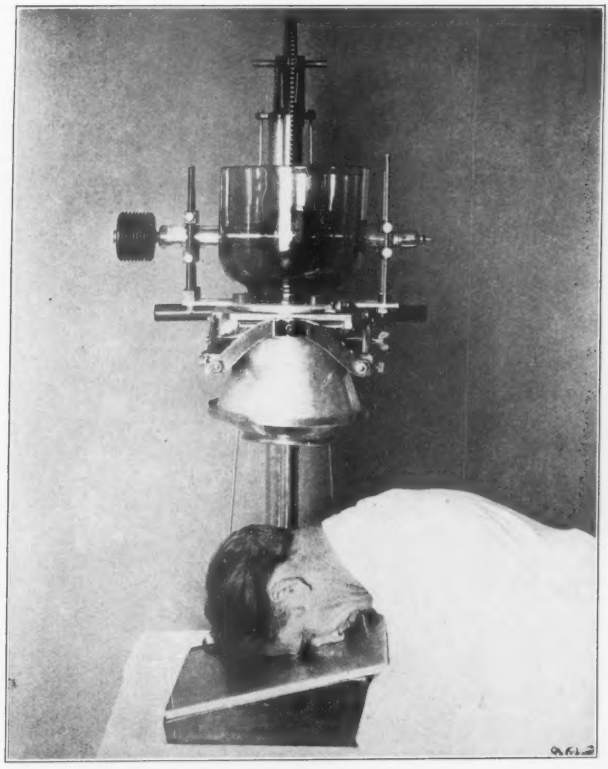

Fig. X. By using the prone Grange position the lateral wall and the floor of the antrum are visible. The heavy superimposed shadows are avoided. Fig. XI shows a film obtained in this position.

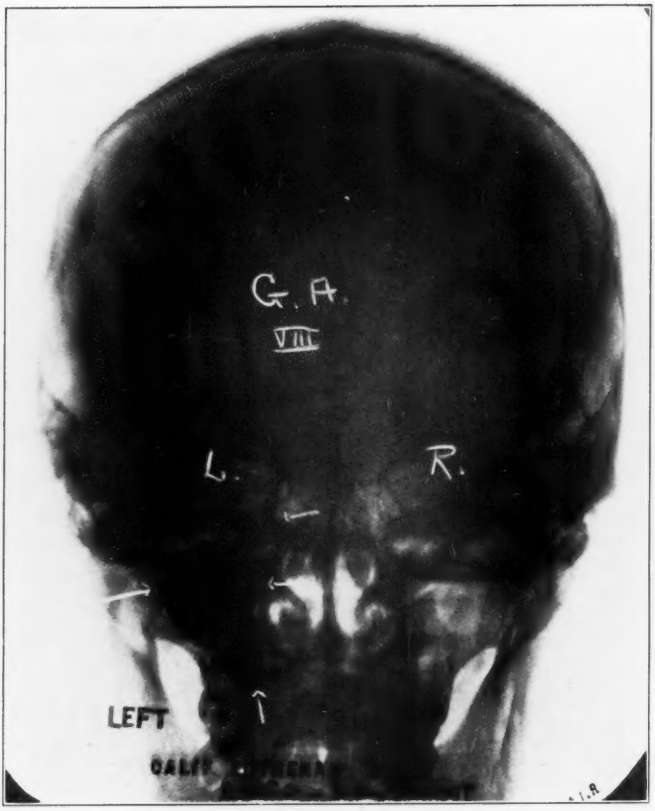

Fig. XI. Campiodol injection of the left antrum, clearly outlines the lateral wall and floor.

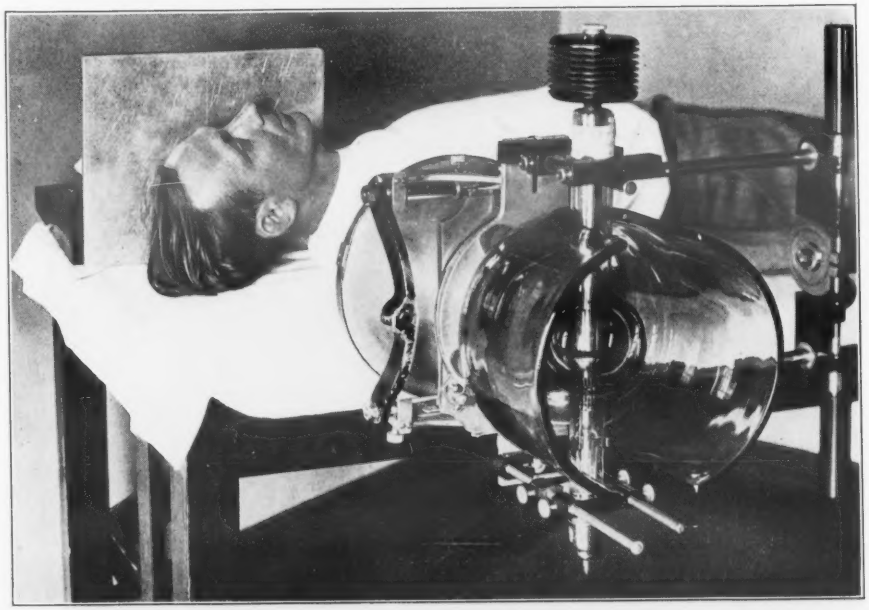

Fig. XII. The lateral supine position outlines the posterior wall and part of the antral floor and roof. Fig. XIII shows this area outlined.

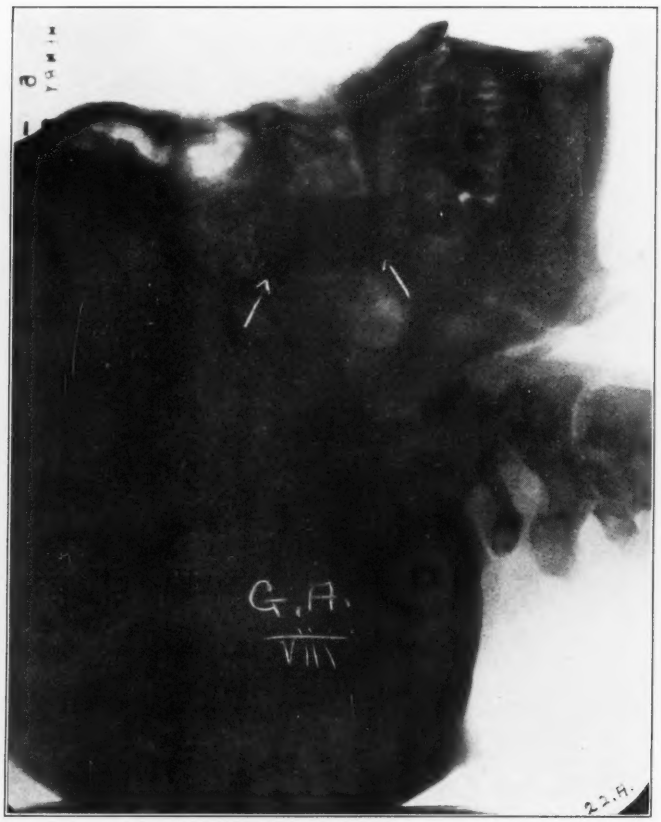

Fig. XIII. Campiodol injection outlining the posterior wall and part of the antral floor and roof.

Fig. XIV. The prone lateral Waters' position gives most of the antrum not outlined in the lateral supine position. Fig. XV shows the opaque media outlining the antrum in this position.

Fig. XV. The antrum outline obtained by Campiodol injection in the lateral Waters' position.

LXXXVII.

ASTHMA: ITS ETIOLOGY AND SURGICAL TREATMENT.*

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Grand Rapids.

Bronchial asthma is not a pathologic entity. It is an allergic anaphylactic or reflex manifestation of local or constitutional pathology, characterized by recurrent attacks of paroxysmal dyspnea. These attacks result from spasmodic contraction of the bronchioles, together with hyperemia of the bronchial mucosa and glandular hypersecretion.

Consequently, the structure of the small and finest bronchioles is of great interest. Miller[1] has reconstructed a terminal bronchiole from serial sections of a lung in full expansion. He demonstrates that cartilage is absent, except for the presence of scattered plaques. The epithelium is cuboidal or squamous, glands are absent and the mucosa lies in folds as though squeezed by the enveloping muscle. The muscle fibers, which in general are circularly disposed, are actually interlaced in a lattice formation. Alveoli arise from the walls of the fine bronchioles. About the necks of these alveoli there is a constricting muscle band, but no muscle is found in the alveolar walls. It has been determined that the proportion of muscle increases as the caliber of the bronchiole diminishes. Miller estimates a 43 per cent muscle decrease in a bronchiole decreasing 65 per cent in diameter. Graucher determined that the muscle bands are five times stronger in a bronchiole of 1 mm. diameter than in one of 10 mm. diameter. There is no muscle group opposed to these constrictors.

The nerve supply comes from the vagus and sympathetic fibers originating in the superior and middle cervical ganglia. These two are interwoven in the anterior and posterior pulmo-

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*Read before the American College of Physical Therapy, November 6, 1929.

nary plexuses from which fibers go to the lung to supply bronchial, vascular and pleural innervation. Some fibers cross to the opposite side. Weber[2] has shown that stimulation of the distal stump of a cut vagus produces constriction on both sides, but more marked action on the cut side. It is not known whether there are secretory fibers to the glands. Mucus probably collects during an asthmatic attack and at the end is probably liberated by relaxation of the mucosa.

Fig. 1. Reconstructed bronchiole with its muscle and subdivisions. (Miller). D. A., Ductulus alveolaris. S. A., Air Sacs. A., Atria. B. R., Bronchiolus respiratorius.

The clinical picture of asthma may be produced by allergy, anaphylactic sensitization, irritation of the branches of the vagus and sympathetic nerves, and, *possibly*, from direct infection or from drainage from the upper respiratory tract. It is conceivable that it may result from functional disturbance of the central nervous system. It is generally accepted that heredity is a factor in 60 to 75 per cent of the cases. Hoffman[3] estimated, in 1926, that there were about 500,000 cases of asthma annually in the United States.

A very large percentage of asthmatics have nasal and paranasal sinus infection of some type. It is stated by some observers that all asthmatics have such involvement. This has not been our experience. Formerly, about 73 per cent of cases presented definite findings in this locality, but since the use of radiopaque oil in our examination of the sinuses, we are able to demonstrate pathology in about 82 per cent of our

cases. This figure is not submitted as a definite one, because only 16 per cent of the cases were under twenty years of age. The latter figure is at considerable variance with the common observations upon the age of incidence of the disease. About 60 per cent of asthmas appear below the age of twenty. It is our impression, however, that further experience with this method of examination will demonstrate a much higher percentage of such infections than has commonly been accepted.

We recognize a very definite group of cases whose incidence depends upon extrinsic sensitizing substances which have nothing whatever to do with the nose and its associated sinuses. At the same time we feel certain that far too much importance has been ascribed to this etiology and far too little serious attention given to the nasal source.

Skin testing for sensitization is a valuable procedure and should be employed to some extent in the appraisal of every case, but the findings are only of value when definitely positive. The mere appearance of a skin reaction is not sufficient proof that the irritant is the cause of the disease. We have frequently cured cases by sinus operation in which we had very positive reaction for two or more of the common allergens. On the contrary, a negative reaction is not proof that the tested substance is not the exciting cause of the disease. The surface cells may not be sensitized or the test may be made on a day when sensitization has *temporarily* disappeared. It is also true that there may be two coexisting sources of irritation in a given case.

We are perfectly certain that many cases result entirely from nasal and sinus pathology. Further, we are equally certain that these cases could be completely relieved of the spasmodic attack if all of the infection could be removed. The effect on the chronic bronchitis and bronchiectasis will depend, of course, upon the structural changes that characterize them. The asthmatic spasm has produced these two conditions. It may be entirely eliminated while they remain.

It is a matter of common observation that many patients have chronic sinus and nasal disease without any trace of asthma. Others have a complicating bronchitis or an associated bronchiectasis without any asthma. This raises the

question of individual sensitization, of allergy or anaphylaxis, and also speculation as to other modes of vagus or sympathetic irritation.

The excellent work of Mullin and Ryder[4] in tracing the lymphatic pathways from the sinuses to the mediastinal and peribronchial lymphatics has demonstrated an etiology for chronic bronchitis and secondary bronchiectasis, but it does not account for the asthma. It is possible that association of branches of pulmonary nerve plexuses with the involved lymphatics may account for the spasm, but it is not probable.

In 1842, Longet demonstrated that stimulation of the cut end of the vagus nerve would produce bronchial spasm. This finding inspired much experimentation and has been confirmed many times since. Francois Franck[5] discovered, in 1889, that either electrical or mechanical stimulation of the nasal mucosa produced bronchial spasm. In the following year, Sandemann[6] confirmed this finding and noted further that the spasm was inhibited when both vagi were cut. Brodie and Dixon[7] confirmed this latter finding in 1903. These observations clearly demonstrated a connection between the fifth and tenth nerves but the reflex association has never been satisfactorily explained.

If the asthma is an allergic reaction, where are the sensitized cells? We know that they frequently exist in the skin and that only cells of certain layers may be sensitive—*a selectivity*. From this we may assume that similar sensitized cells exist in the some one or more structures associated with the spasmodic phenomena. We have no reason to believe that bronchial muscle can contract without nerve impulse, and we appreciate that the mucosa cannot swell without vascular change. Nor can the glands secrete without nervous influence. Consequently, we must assume that the *nerve cells* are a site of allergy.

Do the irritating substances, either intrinsic or extrinsic, act with the cells of the nasal and sinus linings to produce a toxic substance which either irritates the cells of the tenth or sympathetic nerves directly or are carried through the lymphatic and blood streams to irritate the pulmonary plexuses? Or do they act unchanged on the cells? The latter is highly improbable. It seems equally probable that irritation originating in the nose

or sinuses affects the tenth or sympathetic nerves directly. (McClintic) has demonstrated sympathetic nerve fibers in the sinus linings.) Sluder's[8] observation that cocainization of the nasal ganglion will frequently stop the bronchial spasm confirms this idea. We have frequently repeated Sluder's observation.

It is possible that chronic infection produces a very low grade neuritis in the branches of the nasal ganglion which result in the reflex stimulation of the vagus. The absence of local pain, etc., makes this very improbable.

Another point in this connection must not be overlooked. Franck, Sandemann, Brodie and Dixon and others have demonstrated that *mechanical* irritation of the nasal mucosa will produce reflexly, via the vagus, a bronchial spasm. There is no question of allergy here, and we are forced to conclude that there are two types of irritation originating in the nose which can reflexly stimulate the vagus. Irritating nasal contacts must be considered in our appraisal of a case.

It does not seem probable that the process is one of anaphylaxis, because the infection and toxemia are *continuous* from the onset of the lesion, and it is only after it becomes chronic that asthmatic symptoms appear. This process would favor desensitization and immunity rather than sensitization.

Asthma is, primarily, a disease of early life. The etiologic factors in many of these cases, particularly in infancy and early childhood, have nothing whatever to do with the nose and its sinuses. They depend upon the patient's food, bed, plant products, environment or associated animals. At the same time many antrum and ethmoid infections are overlooked during the acute stage, when simple treatment is effective, and allowed to progress to a chronic state, which produces the picture with which we are concerned. We have radically operated upon the antrum of a boy aged twelve to cure an asthma of many months' standing and drained the antrum of an infant three weeks old.

The profession at large, including many rhinologists, need a more intimate conception of the involved anatomy and pathology.

Many years ago, Zuckerkandl[9] demonstrated that the nasal polyp results from chronic inflammation of the mucosa. Hajek[10]

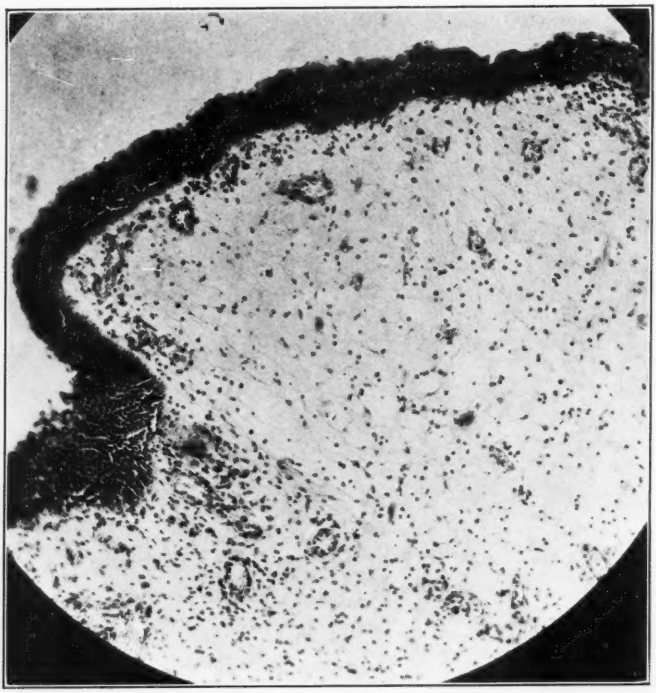

Fig. 2. Polyp showing simple epithelial covering and a very edematous stroma which is infiltrated with inflammatory cells.

later confirmed this and demonstrated that the inflammatory process may involve the entire mucosa and progress to the underlying periosteum and adjacent bone. *The polyp is a result and not a cause.* Its removal occasionally permits the underlying inflammatory process to heal. Volotini[11] reported, in 1871, a complete cure of an asthmatic by the removal of a polyp. There are numerous such reports in the literature since. These are exceptions rather than the rule, however. Polypi are usually sign posts marking a deep-seated and widespread chronic infection or pointing to a diseased sinus. It is obvious that the removal of a result of this infection, with no attention to the pathology itself, can have no value other than a mechanical relief to the airway. Yet we constantly see patients who have had polypi repeatedly removed, with no advice as to the real cause of their conditions. The infection producing the polypi may produce pus, a catarrhal exudation or no moisture whatever. In other words, the mere absence of nasal secretion is no proof of the absence of chronic nasal or sinus infection. An opinion based on mere inspection of the nasal cavity, together with transillumination of the sinuses, is a disgrace to the examiner.

A proper examination requires a family history as to an hereditary tendency to asthma, and a careful rhinologic history which should develop information as to the frequency of colds, abnormal sneezing, constant or periodic watery discharge, etc., as well as all history related to the lower respiratory tract. Further, there should be a careful inquiry concerning the relation of a bronchiospasm to food, to those allergens present in living quarters, to the presence of associated animals and to possible influence of plant substances. This inquiry should be supplemented in cases of suspicion by careful skin testing by either or both the scratch and hypodermic methods. There should be a careful inspection of the nasal cavities proper and a similar examination of the nasopharynx with a mirror, or, better still, with a modern pharyngoscope. The latter affords an excellent view of all of the posterior nasal structures, free from distortions of light, etc. This affords accurate information of the posterior ethmoid region and of the area about the sphenoid ostia. In cases where there is the slightest suspicion the nose should be cocainized and the middle ethmoid area

exposed with a proper speculum. Information gained here will frequently lead to suspicion of the maxillary antra. Transillumination will frequently furnish positive evidence, but a negative finding should never be considered conclusive. In cases where suspicion is directed toward the antrum, the ordinary procedure of puncturing the antrum with a fine needle, employing inflation and irrigation, offers valuable information in many cases, but, again, is not conclusive. The examiner should not overlook the fact that the presence of marked inflammation and hyperplasia is frequently without any surface moisture whatever. The X-ray plate usually reveals the presence of a pathology, but it, too, is not conclusive. The most valuable information is obtained by X-ray examination after the installation of some radiopaque substance, such as lipiodol. This procedure is the most valuable addition which has been made to rhinologic diagnosis in many years. It furnishes much information which could be gained in no other way except by direct inspection. It reveals the presence of hyperplasia, permits the measuring of its extent, exposes the presence of polypi, cysts, etc. Such an examination requires plates taken in at least two, and, better, three positions. The rhinologist and his roentgenologic collaborator must formulate from experience standards which will determine methods of management.

One must not overlook the fact that suppuration and hyperplasia not only occur separately, but are frequently associated in the same sinus. It is the author's impression that hyperplasia is always present in the cases having asthma. There is a wide difference of opinion as to the relative frequency with which the various sinuses are involved. It has been our experience that the ethmoid labyrinths are the most frequently involved in asthmatic cases and also that there is associated involvement of the maxillary sinuses in a very large percentage of these cases. The sphenoids are very frequently the site of etiologic pathology, while the frontals are only occasionally so.

Lorie[12] reports 39 cases of asthma, all having chronic hyperplastic ethmoiditis as the etiology of the asthma. Bishop[13] reports 50 cases in whom this was the main cause of the asthma. Shambaugh[14] states that the etiology is usually hyper-

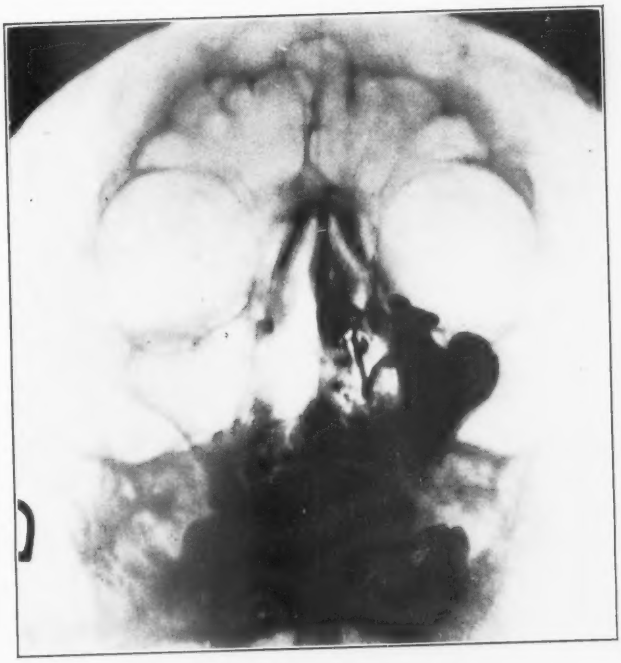

Fig. 3. Complete filling of normal antrum.

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Fig. 4. Complete filling of normal frontal sinus.

Fig. 5. Hyperplastic pyogenic membrane-polypi. Note the opacity of the opposite antrum and the added information gained by injection of lipiodol.

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Fig. 6. Marked hyperplasia. Pyogenic membrane. Polyp on the right side.

Fig. 7. Pyogenic hyperplastic membrane which almost fills the antrum. This case also presented hyperplastic ethmoiditis and sphenoiditis.

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Fig. 8. Chronic inflammation—cyst.

Fig. 9. Large polypus surrounded by a cyst. Note the compression of the cyst by the oil.

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Fig. 10. Lateral view of Fig. 9. Note the compressed cyst in the posterior portion of the antrum.

plasia in the ethmoid labyrinths, but that other sinuses are frequently associated. Brown[15] reports 27 cases, ranging from the ages of four to sixty-two, in which this pathology was the principal factor.

The rhinologist of the past has had such an incomplete appreciation of the pathology involved in these cases and consequently has managed them in such a superficial manner that the results have tended to discredit nasal and paranasal sinus surgery with the profession at large. It is only within a very few years that some practitioners have properly appreciated the situation and resorted to surgical measures which were deemed adequate for the situation.

Kahn[16] reviews 33 cases of nasal operation for asthma, but in none of these cases is any mention made of operative correction of pathology in any of the accessory sinuses. He concludes that "it is not to be expected from an operation on the nose that asthma will be at all influenced." On the contrary, Dundas Grant[17] reports a series of cases in which the involvement was either a middle turbinal pathology or abnormality, or septal contact in which 40 per cent showed recovery and 20 per cent showed improvement.

Lintz[18] estimates that 30.4 per cent of asthmatics and other allergic patients are operated on, but that most of these operations are needless and useless. He concludes that no operation will cure or even benefit asthma or hay fever.

Rowe[19] reports 169 operations on 110 of his patients with only slight relief of asthma in a few cases. He concludes that surgery done with the idea of curing asthma is not successful and wasteful of the patient's time and money.

Sterling[20] reports 300 cases of bronchial asthma and classifies operations done upon 129 of them. These operations are excellent examples of misconception of the actual pathology in these asthmatic cases and are probably characteristic of the types of surgery leading to the former conclusions. Twenty had septum resections, 45 had removal of tonsils and adenoids, 24 had polyp operations and 8 had turbinate operations, and 10 had sinus drainage.

In occasional cases a septum operation will remove the mechanical irritation producing a reflex spasm, but the per-

centage of these cases is so small that no great weight should be given to the procedure when carried out alone. The removal of polypi is simply the removal of the result of infection, with only slight hope of influencing the infection itself. The removal of tonsils and adenoids may be sufficient in isolated cases to effect a cure.

The author is certain that complete removal of all of the infection in these areas in from 70 to 80 per cent of the cases would completely cure the patient. This is not possible in a certain percentage of the cases because of the involved and related anatomy.

Lorie[12] reports 35 cures from radical ethmoid surgery alone in 39 operated cases, the patients ranging from 12 to 65 years of age. Bishop[13] reports 40 per cent of complete cures, 56 per cent of improvement and 2 per cent with no result in a series of 50 cases. Brown[15] reports 6 complete cures, 12 marked improvements, 7 slight improvements and 2 with no result in a series of 27 cases. Dennis[21] reports operations on 28 asthmatics, with 19 improvements, 4 not improved and 5 cases not noted. Stout,[22] in a review of cases seen over a period of four years in the Jefferson Hospital Asthma Clinic in Philadelphia, states that treatment and surgery produced a marked improvement in 22 per cent, a moderate improvement in 42 per cent, a slight improvement in 22 per cent and no improvement whatever in 15 per cent of the cases.

Our personal experience has been somewhat in line with the observers already quoted. A large majority of the patients were cured and all of the remainder were markedly relieved. All of the cases presented a hyperlastic mucosa in the involved sinuses and a number of them had added to this a chronic purulent infection. Several had suppurative and hyperplastic processes involving all of the sinuses, and two of them were complicated by infection and polypoid degeneration of the septal mucosa. In one of these cases the septal polypi recurred three times after removal. The polypi in one case arose from the mucosa in the region of the junction of the quadrilateral cartilage and ethmoid plate and in the second case from the mucosa covering the rostrum. These are the only cases of septal polypi observed by the author in a long experience. Infection of the ethmoid labyrinth occurred alone in 16.2 per

Fig. 11. Hyperplastic sinusitis. Note polyp and intense inflammatory infiltration.

Fig. 12. Hyperplastic sinusitis. Note glandular hyperplasia and intense inflammation.

cent of the cases; of the antrum alone in 34 per cent of the cases; of the sphenoid alone in 5.5 per cent of the cases. The antrum and ethmoid were jointly involved in 44 per cent of the cases. There has been complete cure in 74 per cent of the cases and marked improvement in 26 per cent. Some of the cured cases have been free from symptoms for nine years. There was recurrent ethmoid infection, evidenced by return of the polypi, in 26 per cent of the cases. The surgical procedure demanded for the accomplishment of these results is a most radical one. It has been stated before that the author feels certain that cases of this type can be cured *if all the infection is removed.* This is possible of accomplishment in all of the sinuses except the ethmoid.

Much has been written and said about the conservative surgical management of chronic disease in the larger sinuses. I am absolutely convinced that nothing other than the most radical procedure will serve to totally cure the large majority of chronically diseased sinuses. It is a mistake to accept such statistics as claim cures in 40 to 50 per cent of radical sinus disease by the employment of drainage, irrigation and local treatments. In our experience less than 20 per cent of these sinuses recover under such management. It will be perfectly evident that some of the more conservative of the so-called radical operations will not suffice to accomplish the desired result. The employment of such technic as the Caldwell-Luc operation and the so-called conservative management of the sphenoids accounts for many of the failures to obtain a cure. Even the Denker operation, in which approach to the antrum is made through the canine fossa, is insufficient unless carried out more radically than originally described. The bone removal must be sufficient to permit a clear view of all parts of the sinus and the removal of every particle of its lining. This necessitates the removal of a narrow strip on the anterior antral wall as high as the orbital floor. The failure to thoroughly clear out this anterior superior angle accounts for many bad results. We have had two chronic antra in which there was a complete bony septal wall separating a posterior cavity three-eighths of an inch deep in one case and a half inch in the other. Both presented an ostium into the nasopharynx. In the first case the wall was extremely thin. It was not suspected

and was broken through by accident. It is our practice to entirely remove the antral lining and to immediately replace it with very thin split skin. This management presents many advantages which do not come within the scope of this discussion.

We are frequently told that a proper management of a chronically diseased sphenoid consists in the removal of its anterior wall down to the floor, but that its lining should not be removed. This is not consistent with our practice in the antrum, nor can there be any less justification for leaving a diseased lining in the sphenoid than there is for a similar management of the antrum. It is our practice to completely denude the sphenoid cavities whenever there is indication for radical treatment. The fears, based on the possible presence of dehiscence in the bony walls, are not founded on experience in practice.

The ethmoid labyrinth, because of its structure and its related anatomy, does not, in many cases, permit of a thorough removal of all diseased tissue. All of that portion of the cells which is not represented in the common party wall between the nose and the orbit should be removed. This not only accomplishes the removal of a large quantity of pathologic tissue, but permits free drainage, ventilation and access for treatment to the remaining portion. It is frequently impossible, however, to eradicate infection of the bone in this portion of the cell and in the included mucosa. Hajek demonstrated beyond dispute that infection travels from the surface of the mucous membrane to its depth and involves the adjacent periosteum and bone. The infected mucosa which lies on the surface periosteum and dips into the interstices in the bone sets up an osteitis which is often difficult, and many times impossible to eradicate.

This condition accounts for the recurrence of polypi in this region, as well as for the inability to completely cure the patient. We have employed many agents for the postoperative treatment of this area and have concluded that only radium and ionization of basic salts have been of service to our patients. The radium serves to reduce the bits of remaining mucosa and periosteum to scar and removes this source of chronic infection. It frequently has the effect of preventing recurrence of polypi

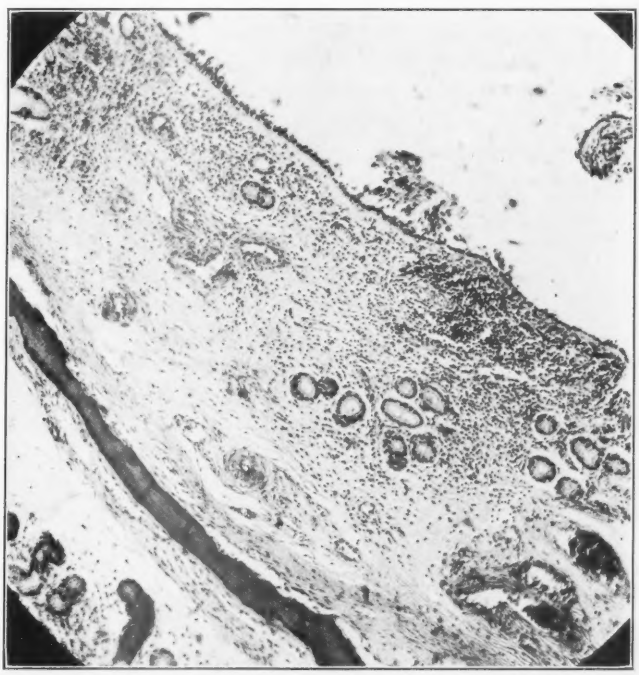

Fig. 13. Mucosa containing stroma densely infiltrated with inflammatory cells. The inflammation extends to the bone beneath. Periostitis. Ethmoid Section.

Fig. 14. Osteitis and periostitis of ethmoid bone. Blood vessels engorged and inflammatory cells grouped through stroma and on the periosteum.

but it has no effect on the deep infection in the residual bone.

We have had numerous excellent results from the ionization of basic salts. The most uniform success has resulted from the solution of zinc, with the following formula:

Zinc sulphate ..... 1.87 g.
Glycerin.....30 "
Aquae q. s. ad 1000.

The treatment is begun ten to twelve days following radical resection of the ethmoid labyrinth. Cotton soaked in solution is packed over the entire area to be treated and is so arranged as to include a zinc terminal which is one-eighth inch in diameter and one and one-half inch long. From three to five milliamperes of current is used for forty-five minutes on successive days until success or failure is apparent. In those cases treated successfully the improvement becomes apparent after three or four treatments and the cure is generally accomplished by a series of eight to twelve treatments.

The practitioner should recognize this characteristic of ethmoid infection and be prepared for a recurrence of its evidences, as well as persistence of the resulting symptoms in a milder degree. *It is the condition of this area alone which prevents complete cure of asthma resulting from sinus disease.*

Our conclusions are these:

1. A very large percentage of asthmas depend on chronic sinus disease.

2. The asthma may result from a coexisting sinus disease and the presence of some extrinsic allergen.

3. Many cases are not diagnosed because of inadequate methods of examination. Lipiodol injection and suffusion are of great service.

4. Surgery in asthma cases has been discredited because of the poor conception of the involved pathology and insufficient surgery for its removal.

5. In ethmoid infections, complicated by bone involvement, it is not possible to totally remove the disease in all cases. Infection may persist and polypi recur. All of the other sinuses may be totally cleared of infection.

6. Only the most radical surgery will be adequate.

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LXXXVIII.

AN ANALYSIS OF THE LIMB RESPONSES TO SEMICIRCULAR CANAL STIMULATION IN THE FROG.*

By John Tait, M. D., and W. J. McNally, M. D.,†

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It has been generally known for a long time that the labyrinth exerts some control over the movements and attitudes of an animal. As early as 1693, Bannister described balancers in certain flies. Flourens (1824) and De Cyon (1878) found that, after injury or section of a semicircular canal in the pigeon, the rabbit and the frog, the animal was very much disturbed and tended to fall over in the plane of the injured canal (Byrne, 1912). Kreidl found that interfering with the ear stone in the crayfish caused marked disturbance of equilibrium and that by substituting iron filings for the otolith in the otocyst the animal can be made to assume different attitudes by bringing a magnet near the head of the animal. The magnet causes a shifting of the iron filings in the otocyst. Kreidl also found that fish show a definite response to centrifugal force by leaning in toward the center.

Two Groups of Labyrinthine Reflexes.—Breuer (1874) was the first to point out two different groups of labyrinthine reflexes. He gave as his opinion that the reflexes due to movement arise in the semicircular canals and the reflexes resulting from position arise from the otolithic organs. For many years interest was centered chiefly around the semicircular canals and their effect upon eye and head movements.

*Note: The authors wish to express their indebtedness to the American Academy of Ophthalmology and Oto-Laryngology for the monetary grant made to W. J. McNally, Research Fellow of the Academy in Oto-Laryngology, part of which was used to defray some of the expenses of this research.

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Otolithic Reflexes.—Magnus and de Kleijn were the first to make a detailed study of the labyrinthine reflexes with a view to determining more especially the otolithic reflexes and their effect upon the body musculature. They have shown that the otolithic reflexes are concerned with the movements and posture of the body as a whole and that they cooperate with and are influenced by reflexes from other parts of the body.

Semicircular Canal Reflexes.—Our efforts have been devoted for the most part to the study of the control exerted by the semicircular canals upon the limbs and body musculature in contradistinction to the more widely known relation of the canals to head and eye movements.

Centrifugal Force.—Our first attempt was to differentiate in a frog, subjected to turning about a vertical axis, between the response to pure angular acceleration and the response to centrifugal force. It is well known that if a frog is subjected to turning (angular acceleration) about a vertical axis in the horizontal plane, it responds by walking around in the opposite direction. If the frog is far away from the center and the turning becomes rapid, the animal tends to lean in towards the center. In our experiments we attempted to eliminate the effect of angular acceleration by increasing the speed of rotation so slowly as to render it imperceptible to the frog. In other words, angular acceleration was maintained below the threshold of stimulation for the frog. By this method, it was possible to place a frog on a turn-table, side to the center, and to develop quite a high speed of rotation without the animal showing any tendency to make turning movements in any direction. We found, however, that as the speed of rotation was increased, the animal began to lean in towards the center by flexing the limbs on the inside and extending the arm and leg away from the center of rotation. This lean was increased until the speed of rotation became so high the animal could no longer maintain its footing. A frog, after bilateral labyrinthectomy, does not show this protective response to centrifugal force, and, like an inanimate object, is thrown off the table as the speed of rotation increases. However, a frog with all six semicircular canals removed, though it does not respond to ordinary turning or angular acceleration, shows a normal response to centrifugal force when subjected to turning by

the method just described. A frog with the nerves to both saccular maculæ cut also shows a normal response to centrifugal force.

This response of the limbs and body musculature to centrifugal force is labyrinthine in origin and most probably arises from the intact utricular maculæ. It is, therefore, an otolithic response, whereas the ordinary response, usually described, which follows turning of an animal in the horizontal plane about a vertical axis, is the true semicircular canal effect and is abolished after the removal of all six semicircular canals.

Gravity Stimulation.—We also found that the posture or attitude assumed by a normal frog when subjected to centrifugal force could be elicited by simply tilting the frog slowly out of the horizontal plane. The frog responds by flexing the upper arm and leg and by extending laterally the arm and leg on the lower side, the result being to maintain the head as nearly as possible in the horizontal plane. This response is not possible in a frog with both labyrinths removed. It is possible to elicit this response after removal of the ampullæ of all six semicircular canals, and after section of the nerve to both saccular maculæ. This protective response, therefore, also arises from the utricular maculæ. In this last case, the attitude is assumed in response to gravity stimulation. The head is maintained at right angles to the pull of gravity, whereas when the frog is subjected to centrifugal force, it adopts an attitude wherein the head is maintained at right angles to the resultant of the pull of gravity and the pull exerted by centrifugal force at any given moment during the turning. This is an otolithic reflex—utricular in origin.

Stimulation of Horizontal Semicircular Canal.—As we have already mentioned, an animal subjected to rapid turning in a horizontal plane responds by turning its head and eyes in the opposition direction, and in some cases, as in the frog, the animal tends to walk around in the opposite direction, as though it were trying to retain its original field of vision. Ewald found that when one horizontal canal was injured in the pigeon, the animal responded normally to turning to the intact side, whereas there was only a very slight response of the head and eyes to turning to the operated side. Ruttin found that this is also

the case in the human, that there is a slight response to turning to the operated or diseased side. Maxwell, McNally and Tait and others found that after destruction of one horizontal ampulla in the frog the animal responds normally to turning to the intact side, but there is no response whatsoever to turning to the operated side.

Stimulation of a Vertical Semicircular Canal.—De Cyon (1878) found that after injury to the vertical canals in the frog the animal was very much disturbed and that it tended to fall in the plane of the injured canal. In our investigation of the semicircular canals in the frog, rather than try to injure the canal, we attempted completely to destroy, by cautery, the ampulla of a particular canal without injuring any of the other labyrinthine structures. After injury of a vertical canal, we found that when at rest the animal is for all practical purposes quite normal. However, if the animal is tilted out of the horizontal plane about a horizontal axis it lacks some of the protective movements which are executed so promptly by the normal frog.

The normal frog, when quickly tilted out of the horizontal plane, makes a rapid protective movement or readjustment of the limbs, which tends to maintain the head in its original position in space. For example, if a frog is quickly tilted forward, the head is raised off the table, the arms being extended forward. If the animal is tilted backwards quickly, the head is lowered, the arms are extended laterally and slightly backwards and the legs are extended backwards. This rapid readjustment of the limbs and of the body places the animal in the same attitude or posture as that which is assumed when the animal is very slowly tilted out of the horizontal plane as has been previously described. This rapid response to tilting out of the horizontal plane is not present in a frog after a bilateral labyrinthectomy nor is it present after removal of all six semicircular canals. This rapid protective movement is, therefore, elicited from the intact semicircular canals.

Earlier Impressions.—In our earlier attempts at analyzing the protective reactions of a normal frog to rapid tilting about a horizontal axis, we came to the conclusion that a semicircular canal responded best to a movement in its own plane and that it responded to tilting in only one direction, while a

vertical canal controlled chiefly the movements of the limbs of the corresponding corner of the body. If a normal frog is tilted forward in the plane of one of the anterior vertical canals, the most obvious response is a thrusting or extension forward of the arm of the corresponding corner of the body. If the tilting is in the plane of the right anterior vertical canal, the right arm is extended forward, the right corner of the head being raised. If the ampulla of the right anterior vertical canal is destroyed and the animal is tilted forward in the plane of this canal, the head dips forward and to the right, the most evident abnormality being a failure to extend the right arm. Hence the conclusion that a vertical canal controls chiefly the movement of the limb of the corresponding corner of the body. In spite of this conclusion it seemed obvious that following the destruction of the ampulla of any one vertical canal, there was more than the lack of extension of the limb of the corresponding corner of the body—some movement in the other three limbs—but as these things were not so obvious and were more difficult to describe they tended to be overlooked. It seemed probable that one semicircular canal was concerned with the rapid response of the limbs of both sides of the body and subsequent observation seems to confirm this.

Reaction of a Normal Frog.—When a normal frog is placed on a tilt-table having a horizontal axis and the frog is rapidly tilted to either side, it makes a very rapid readjustment of the limbs, which tends to maintain the head in the horizontal plane. There is no swaying of the head or body. If the tilting is to the left, the left arm is extended laterally, the right arm is flexed and is held close to the body. This readjustment is so rapid that the head does not seem to move from its original position in space. If the tilting is through a small angle in space, the palms of the hands do not shift their base, but if the tilting is through a wide angle, the left arm, as well as being extended, moves farther down the board, and the left leg may be extended laterally.

If the frog is rapidly tilted backwards through a small angle, the arms are flexed so that the head is brought nearer to the table and the legs may be slightly extended—that is, the knees tend to move laterally from the side of the body. However, if the tilting backwards is through a wide angle, the

arms extend laterally, the palms of the hands being turned backwards as though prepared to make a "breast stroke" as does a man when swimming. The legs are extended backwards.

When rapidly tilted forward, as through a small angle, the arms are extended forward so that the head is raised from the table; if through a wide angle, the arms are moved forward on the board. The legs do not seem to move, but the body seems to move back on the flexed thighs.

These protective reactions to rapid tilting are evidently complicated movements and they involve the limbs on both sides of the body—all four limbs in each movement. If both labyrinths have been removed or if the ampullæ of all six semicircular canals have been destroyed (McNally and Tait, 1925), these protective movements to rapid tilting are abolished. When quickly tilted out of the horizontal plane in any direction, such an animal simply falls over as the rapid protective movements do not occur. If the utricules are still intact—that is, if only the canals have been removed, the animal later picks itself up and slowly assumes the normal protective attitude for the new position. This is a utricular response to gravity and not the rapid protective response from the semicircular canals. These rapid protective reactions are, therefore, dependent upon an intact semicircular canal mechanism.

ABLATION EXPERIMENTS UPON THE SEMICIRCULAR CANALS.

The proof that one semicircular canal exerts an influence over the movements of the limbs of the opposite side of the body will be seen from the following experiments:

In all the experiments about to be described, where one or more of the ampullæ of the semicircular canals have been injured, the reactions of the animals to centrifugal force and to slow tilting or gravity reactions are all normal and, therefore, will not be referred to again.

Destruction of the Ampulla of Left Horizontal Canal.—When placed on a turn-table and turned to the right, a frog reacts normally by walking around to the left. This requires the normal movements of all four limbs. When the animal is turned to the left, it does not react but remains quietly at rest.

The intact right horizontal semicircular canal has evidently elicited reactive movements from all four limbs.

Destruction of the Ampulla of the Left Anterior Vertical Canal.—When placed on a tilt-table and tilted rapidly to the right, the animal responds normally by extending the right arm and flexing the left, so that the head is held in the horizontal plane without any swaying. When tilted to the left, the head sways slightly to the left, the left arm not being promptly extended or the right arm flexed. This absence of flexion of the right arm is quite as definite as the absence of extension of the left arm. The rapid tilting to the left, therefore, throws the head slightly to the left before the flexion of the right arm and extension of the left arm take place. In our earlier description of this experiment (McNally and Tait, 1925), we failed to stress the fact of the absence of the flexion of the right arm. When tilted to the right, the intact right anterior vertical semicircular canal elicits the normal extension of the right arm and flexion of the left arm, therefore, influencing the limb movement on both sides of the body. If the animal is tilted forward in the plane of the injured left anterior vertical canal, the abnormal response is more marked, the head tilts downward and to the left, the left arm not being promptly extended forward and laterally; the right arm is not flexed and rather gives the impression of some extension. There is no evident movement of the hind limbs. It is only after an appreciable time that the animal picks itself up and assumes the normal protective attitude for the new position. When it is tilted backwards in the plane of the injured canal, the response is normal. When tilted forward, the head dips down and to the left, the left arm not being promptly extended. The right arm is extended and seems to push the head over to the left. When tilted backwards, there is no obvious abnormal response.

Destruction of the Ampulla of the Left Posterior Vertical Canal.—If tilted backward in the plane of the injured canal, the head tends to go backwards and to the left. It is raised off the table, evidently due to some abnormal response of the right arm, which is difficult to make out. It may be the absence of the "breast stroke" with the right arm, which would tend to pull that corner of the body downwards and forwards. The legs are not extended, and if the tilting is rapid and

through a wide angle, the animal is very easily thrown off the table. If tilted forward in the plane of the injured canal, the reaction is normal. When tilted strongly backward—that is, the long axis of the frog being at right angles to the axis of the table, the head sways back and to the left. The right leg is extended back and to the right, the left leg remains flexed or may be extended just a little. The arms seem to extend laterally but evidently not normally, because the right side of the head is raised. When tilted forward the reaction is normal. When tilted back in the plane of the intact right posterior vertical canal, the response is normal—that is, the head is lowered to the table, both arms are extended laterally, the palms facing backwards and both legs being fully extended. This normal extension of the arms and the extension of both hind legs, when tilted in the plane of the intact posterior vertical canal, is evidence of the effect that the intact posterior vertical canal elicits normal cooperative movements from all four limbs.

Destruction of the Ampullæ of Both Posterior Vertical Canals.—When the animal is placed with its long axis at right angles to the axis of the tilt-table and tilted forward, the reaction is normal. When tilted backward, the head rises off the table backwards, and there is an absence of lateral extension of both arms—the "breast stroke" previously described. The legs are not extended and if the tilting is through a wide angle, the animal is very easily tumbled over backwards. In this experiment the absence of the posterior vertical canals is responsible for an abnormal movement of both the arms and the legs.

Destruction of the Ampullæ of Both Anterior Vertical Canals.—When the frog is placed on the tilt-table with its long axis at right angles to the axis of the table and is tilted backward, the reaction is normal. When tilted forward, the head slews downwards and forwards, the arms, instead of being promptly extended forward, seem to be thrown out laterally, and though there is no obvious movement of the legs the body seems to slide away from the flexed thighs. After an appreciable time, the animal picks itself up and assumes a normal protective attitude. This experiment shows control of the anterior pair of canals over the fore and hind limbs.

Destruction of the Ampullæ of All Three Semicircular Canals on the Left Side.—When tilted forward, the response is that of an animal with a left anterior vertical canal destroyed. When tilted backward, it shows the response of an animal after destruction of the left posterior vertical canal. When tilted to the left, it shows the slightly more exaggerated response of an animal with the left anterior vertical canal destroyed. When tilted to the right, the response is normal. On the turn-table, there is no response to turning to the left.

Destruction of the Ampullæ of All Six Semicircular Canals. —On rapid tilting in any direction the animal slews over in that direction, making no prompt effort to protect itself. It has lost its rapid protective reaction to movement in any direction.

Summary.—From these experiments, it seems evident that a semicircular canal rather than affecting the movements of any one limb or of any one group of muscles is directly concerned with the protective reaction of all four limbs to movement in its own plane—that is, it controls a different group of muscles in different limbs, depending upon the direction and plane of the movement. It would seem more correct to speak of a semicircular canal as controlling all groups of muscles concerned in the rapid protective reaction to a sudden movement in its own plane and in the direction in which the ampulla points.

EXPERIMENTS ON THE RECORDING TILT-TABLE.

In attempting to make a more careful analysis of these various limb responses to semicircular canal stimulation, the idea was conceived by Dr. Tait to separate a decerebrate frog into two components. This was accomplished by dissecting free the sciatic nerve, the thigh bone and muscles being cut away, leaving the lower leg segment connected to the body component by the intact sciatic nerve only. In this way it proved possible to subject the body component to rapid tilting while the limb which rested on an adjoining table is only affected by impulses carried to it by the intact sciatic nerve. It was found that in the decerebrate frog, otherwise normal, backward rapid

tilting of the body component caused a kick of the limb component.

Recording Tilt-Table.—An apparatus was gradually evolved whereon the flexor and extensor muscle groups of the ankle could each be connected to a lever recording on a smoked drum. The apparatus became further modified till in its present form it is possible to investigate the extensor and flexor muscle groups of both ankles simultaneously. The apparatus consists of a fixed stand, to one side of which is attached a small table which may be tilted up or down. On the other side of the fixed table are arranged four levers in pairs, one above the other, the points of which are so arranged as to write on a vertical drum one above the other. (See Fig. 1.) From the tilt-table there is also a lever which records the movements of the tilt-table; thus from the kymogram can be seen the moment when the tilt begins and the rapidity with which it is carried out, and the height of the tilt, etc. A time tracing is added from an electrically controlled tuning fork. From a study of the kymogram, therefore, it becomes possible to calculate the length of time taken by a muscle group to respond from the moment that the tilt is given to the body segment.

Preparation of the Animal.—Both limbs are prepared by dissecting out the sciatic nerves and removing the thigh portion of the leg. The tendons of the anterior or flexor group and posterior or extensor muscle group of the ankle joint are then dissected out and a ligature applied to each. The foot is then amputated at the ankle. The leg segment is held steady to the fixed table by transfixing the knee joint with a pin. The ligatures from each tendon group are then attached each to a separate lever. The body segment is fixed to the adjoining tilt-table by cotton bands, the sciatic nerve loosely bridging the axis of the table. (See Fig. 2.) The nerve is kept moist by continuous saline applications. The body segment may be arranged with the long axis of the frog at right angles to the axis of the tilt-table, or it may be slewed to either side in the plane of one of the posterior vertical canals.

Preoperative Examination.—Before any operation is performed, the animal is carefully examined on the turn-table and on the ordinary tilt-table for the reactions of the normal frog to rapid turning about a vertical axis and to slow and fast tilt-

ing about a horizontal axis. Using the new recording tilt-table, the reactions of the normal decerebrate frog were first studied, then different labyrinthine operations were performed and the resulting effect upon the recording muscle groups was studied from the kymograms.

Some Observations Derived From Examination of the Normal Frog.—The most striking thing under the conditions of these experiments is that the animal does not respond to mere slow tilting or gravity stimulation—i. e., the muscle groups connected to the levers show no response to the slow moving up or down of the tilt-table.

Repeated examination of the normal decerebrate frog on the recording tilt-table revealed the fact that to backward tilting the flexor muscles of the ankle of each side show more constant and greater response than the extensor muscles—the gastrocnemii.

The character of the response of the muscle groups of the ankle joint to semicircular canal stimulation is "twitchlike" and reminds one of a tendon jerk. They can be readily and regularly graded by the degree of angular acceleration imparted to the head body component on the tilt-table. From the tracing or kymogram, it is possible to measure the time required from the beginning of the tilt to the occurrence of the muscle twitch, which is the latent time of the reflex muscle response. By measuring this off on the time tracing, the actual reaction time is arrived at. The shortest recorded reaction time of the muscle group response to semicircular canal stimulation is 35σ.

Examination After Operation on the Ampullæ of the Semicircular Canals Bilateral Labyrinthectomy.—When such an animal is examined on the recording tilt-table, there is no response from any of the recording muscle groups, no matter how rapid the tilt or what the orientation of the body segment. However, if the table is jarred, there is an immediate response of all four muscle groups (stimulation of receptors other than the labyrinths).

Destruction of the Ampullæ of All Six Semicircular Canals.—When on the recording tilt-table there is no response from any of the recording muscle groups to tilting of the body seg-

ment, no matter in what orientation or how rapid the tilting. From these two experiments, it becomes evident that the "twitchlike" response of the muscle groups of the ankle to backward tilting of the body segment is labyrinthine in origin, from the semicircular canal mechanism, as it is abolished by their removal. It is not otolithic in origin.

Right Sided Labyrinthectomy.—When the flexor and extensor muscle groups of both ankles are recording and the body segment is arranged with its long axis at right angles to the axis of the table, and the table is tilted rapidly backwards, the greatest and most constant response is from the flexor muscle group of the left ankle, the response from the extensor muscle group of the left ankle being less marked. There is only an occasional weak response from the flexor muscle group of the right ankle and an even less marked one from the right extensor muscle group.

In the unilaterally delabyrinthized preparation, a fairly constant reflex of the arms was noted. Owing to the unilateral labyrinthectomy the animal leans down to the operated side—that is, after a right-sided labyrinthectomy the right arm is flexed and the left arm extended. The body segment was restrained by a cotton band over the pelvis. On backward tilting the right arm is moved outwards, backwards and forwards like the movement of a man swimming breast stroke when he wishes to dive forwards and downwards. On completion of the upward tilt, the arm is flexed and returned to its original position. The left arm is slightly more extended, the palm being turned backwards and upwards. By these movements both arms are often raised off the ground so that the animal rests on its sternum. This reflex seems most marked in these unilaterally delabyrinthized animals. It seems to be an exaggeration of the normal lateral extension movement of the arms in response to extreme backward tilting.

Destruction of the Ampullæ of the Three Semicircular Canals of the Left Side.—Examination before preparation of the limbs for the recording table showed the gravity reactions to be normal—that is, both utricular maculæ were responding. The animal showed the usual abnormal responses to tilting in the planes of the absent canals. When on the recording tilt-table, to backward tilting, the arms showed the "breast stroke"

reflex previously described but less marked than in the animals with unilateral labyrinthectomy. The chief muscle response to backward tilting was from the flexors of the right ankle. There was a less marked response from the flexors of the left ankle. The extensors of both ankles scarcely responded at all.

Destruction of the Left Posterior Vertical Ampulla.—This experiment will be described in more detail, to give a better idea of the method of procedure.

Complete Report of Experiment.—May 13, 11 a. m. Under ether anesthesia, using a previously examined decerebrate frog, the left posterior vertical ampulla was exposed through the roof of the mouth and the ampulla was destroyed with the actual cautery.

4 p. m. Frog in good condition. On ordinary tilt-table shows loss of response to tilting in the plane of the left posterior vertical canal. The hind limbs were prepared for the recording tilt-table by dissecting out the sciatic nerves and severing the thigh. Only the flexor muscle group of each ankle was attached to the recording levers.

Tracing 1.—Long axis of the body at right angles to axis of tilt-table. The only muscle response was from the right flexors. (See Fig. 3.)

Tracing 2—The same orientation of body segment. Chief response is from the right flexors, there being a slight response from the left flexor muscle group.

Tracing 3.—The body segment slewed over to the left in the plane of the injured left posterior vertical canal. To backward tilting there is no response from either recording muscle groups. (See Fig. 4.)

Tracing 4.—Frog slewed well to the right in the plane of the intact right posterior vertical canal. Backward tilting elicited a very marked response from the right flexors and a less marked response from the left flexors. (See Fig. 5.)

Tracing 5.—Same orientation of the body segment. Backward tilting elicited a marked response from the right flexors and a less response from the left flexors.

Tracing 6.—Animal slewed well to the left. No response from either muscle group except when table was jarred, when both muscle groups responded.

Tracing 7.—Same orientation of body segment. To backward tilting no response from either muscle group.

Tracing 8.—Body segment slewed to the right in plane of the right posterior vertical canal. Backward tilting elicits a marked response from the right flexors, and a less marked response from the left flexor muscles of the ankle joint.

This experiment furnishes very definite evidence to the effect that one posterior vertical canal may elicit a response from the limbs on the opposite side of the body.

Destruction of the Ampullæ of Both Posterior Vertical Canals.—Only one such animal was tested on the recording tilt-table, so that one cannot conclude very much from the result, but it is interesting to note that with all four muscle groups recording, there was no response to backward tilting from any of the muscle groups, no matter what the orientation of the body segment. This frog was in good condition.

Destruction of an Anterior Vertical Ampulla.—Injury to one or both anterior vertical canals did not have any definite or constant effect upon any of the four recording muscle groups of the ankle joint when the frog was subjected to backward tilting.

Postmortem Examination.—The experiments described were all controlled by carefully performed postmortem examinations of the labyrinthine lesion, using the dissecting microscope. It was hoped to show microscopic serial sections of some of these labyrinths, but as they are not yet ready for section they cannot be included in this present presessional copy.

Summary.—This method of examining the leg muscle response on the recording tilt-table has added a very striking proof to what we already observed—that is, that the limb responses to semicircular canal stimulation are an extremely rapid and prompt protective response to any sudden movement or acceleration affecting the head body component of the animal, the reaction time of the recorded twitch being only 35σ. The "twitchlike" character of the response shows that it is not maintained, but, as we have already pointed out, the new position which is so rapidly assumed must be maintained by reflexes from the more slowly responding utricule, which are static in character.

OTHER REFLEXES WHICH INTERFERE OR COOPERATE WITH THE LABYRINTHINE REFLEXES.

The absence of response to gravity stimulation under the conditions of the experiments on the recording tilt-table was at first surprising. To hold the head and body component and to prevent pulling on the sciatic nerve, the head body component is fixed securely by cotton bands which interlace over the back of the frog and are pinned to the cork of the tilt-table.

As a control of this retaining method, to see if it might explain the absence of gravity responses, several experiments were carried out.

A simple instrument was devised, consisting of a small piece of cork, which just covers the under surface of the abdomen. The skin of the abdomen is pinned to the edge of the cork on each side, fore and hind, in such a way that the limbs are quite free to move. To the bottom of this cork a rod may be attached so that the animal can thus be raised off the ground.

Examination of the Normal Frog.—If a decerebrate frog, which has been previously found to respond normally to slow and fast tilting, is attached to the cork platform, it still jumps about and responds normally to slow and fast tilting, even with the cork attached to its abdomen. However, if the platform is raised off the ground and is held by the rod so that the limbs are now free in the air, the frog no longer responds to slow or fast tilting. It seems to have lost its gravity responses and does not seem to show any of the head-righting responses which are described by Magnus in mammals. In some cases, if a larger platform is slid up the rod to make a solid contact for the animal's legs, the frog may assume a normal attitude for whatever position it is in, but as a rule there is very little response to either slow or fast tilting. If this same frog is now freed from the platform it immediately responds normally in every way to slow and fast tilting and jumps about normally.

The absence of limb contact with the ground or the restraining of the body segment to the platform has in some way interfered with the normal labyrinthine responses of the animal, so that the restraining of the body segment under the conditions of our experiments on the recording tilt-table may

in part explain the absence of response to slow tilting or gravity stimulation.

Another experiment was tried, which consisted of applying a mattress suture to the skin on each side of the abdomen. One suture was applied behind the insertion of the arms and another just in front of the insertion of the thighs. The sutures were tied tightly, thus making two tight bands of skin about the animal's body. These frogs responded normally to slow and fast tilting. In other animals tight ligatures were tied around the body behind the arms and around the pelvis. These animals also responded normally to slow and fast tilting. It is, therefore, not merely tight pressure on the body segment which interferes with the labyrinthine responses.

Examination of the Operated Animal.—Several experiments were carried out on unilaterally delabyrinthized frogs. When pinned to the platform and held with the limbs free in the air, the body is held almost normally symmetrical. The lean to the operated side almost completely disappears, the arms being flexed under the platform in a clasp reflex, both arms being quite symmetrical. If a flat surface is slid up under the animal to give its arms and legs contact, immediately the limbs on the operated side are flexed and the limbs on the intact side are extended. These experiments would seem to show that some tactile or kinesthetic factor from the pads of the feet is also necessary for the maintenance of the characteristic unilateral labyrinthectomy posture.

It was also observed that when a frog with unilateral labyrinthectomy was carefully handled and the twist of the body was undone by clasping the head between the thumb and forefinger and slowly bringing the head into the horizontal plane, the new position of the head is maintained after the head is freed so long as the animal is undisturbed. Breathing movements are not sufficient to undo the new posture. Jarring of the table, etc., however, immediately brings about a reassumption of the usual unilateral labyrinthectomy posture.

Summary.—From these control experiments, it becomes evident that, as shown by Magnus for the mammal, there are also in the frog other reflexes which supplement and modify the labyrinthine reflexes in controlling the posture and movement of the normal frog, even though the labyrinthine righting

reflexes on the head are not so evident in the frog as they are in some higher animals. It is, therefore, not surprising, in our recording tilt-table experiments where the body segment of the frog is bound to the table and kinesthetic sensations from the limbs thus interfered with, that there is no evident response of the muscle groups of the ankle joint to slow tilting or gravity stimulation.

SUMMARY.

In earlier experiments we were able to show that a frog, subjected to turning about a vertical axis, makes a different response to centrifugal force than it does to angular acceleration. The response to angular acceleration is the generally known turning of the frog in the opposite direction to the turning of the table. This is abolished by removal of all six semicircular canals. The response to centrifugal force is a leaning towards the axis of turning. This reaction is absent after bilateral labyrinthectomy, but it is not affected by removal of the ampullæ of all six semicircular canals or by section of the nerves to both saccular maculæ. This reaction to centrifugal force, therefore, most probably arises from the utricular maculæ.

The same attitude which is assumed in response to centrifugal force can be elicited by simply tilting the frog out of the horizontal plane. It responds by leaning up the tilted plane, as it were. This latter response is a reaction to gravity stimulation.

After removal of all six semicircular canals, it was found that the frog still responds to gravity and centrifugal force but that it has lost its prompt protective response to rapid movement or tilting. Injury or destruction of the ampulla of a semicircular canal causes a loss of the prompt protective response to any sudden movement in the plane of the injured canal. It was first thought that the absence of prompt extension of the limb of the corresponding corner of the body was the chief result of injury to a single vertical canal.

More careful investigation has since revealed the fact that the protective response to tilting in any one direction consists of extension of the limb on the side toward which the animal is tilted and the flexion of the limbs of the opposite side. After

destruction of one ampulla, the absence of flexion in the limbs of one side is just as marked as the absence of extension of the limbs on the side to which the animal is tilted. It, therefore, seems more correct to consider a semicircular canal as influencing the response of all four limbs to any sudden movement in the plane of that canal and in the direction in which its ampulla points.

This has been further substantiated by examining the animal in two components on an instrument specially designed—a recording tilt-table—whereon the muscle groups of the ankle joint are connected to levers so that the responses may be graphically recorded.

From these experiments it was determined that the response to backward tilting of a decerebrate frog otherwise normal is a "twitchlike" response, the reaction time of which is exceedingly short, 35σ, confirming the idea of the rapidity of the protective response from the semicircular canals. The flexor muscles of both ankles respond to backward tilting more than the extensors, and after unilateral labyrinthectomy or after destruction of the ampulla of one posterior vertical canal the response is greater from the flexor muscles of the ankle of the intact side.

Tilting in the plane of the injured canal elicits very little response from any muscle group, whereas tilting in the plane of the intact posterior vertical canal elicits a fairly marked response from both hind limbs and also from the fore limbs, showing that the intact canal is influencing the movement of all four limbs.

It was found that the head-righting reactions described by Magnus in the mammal are not so evident in the frog. Strapping the animal or removing contact from the feet does interfere with its usual labyrinthine reactions, showing that, as described by Magnus for the mammal, there are other reflexes which supplement or modify the labyrinthine reflexes controlling the posture and movement of the normal frog.

CONCLUSIONS.

1. Reactions of a frog to turning about a vertical axis are in response to two factors—acceleration and centrifugal force.

2. The tendency to turn in the opposite direction to the rotation is in response to angular acceleration and is elicited from the semicircular canals.

3. The tendency to lean in to the center of the turning table is in response to centrifugal force and is most probably from the utricules.

4. One vertical semicircular canal influences the protective responses of all four limbs to rapid tilting in the plane of that canal and in the direction in which its ampulla points.

5. One posterior vertical semicircular canal elicits a response from the flexor muscles of both ankles, but more marked from the muscles of the same side.

6. The muscle response to semicircular canal stimulation is "twitchlike" and extremely rapid, the shortest recorded reaction time being only 35σ. The frog does not show the labyrinthine head-righting reactions which Magnus described in the mammal.

7. The labyrinthine reflexes in the frog are affected by reflexes from other parts of the body, which supplement or modify them in controlling the posture and movements of the normal frog.

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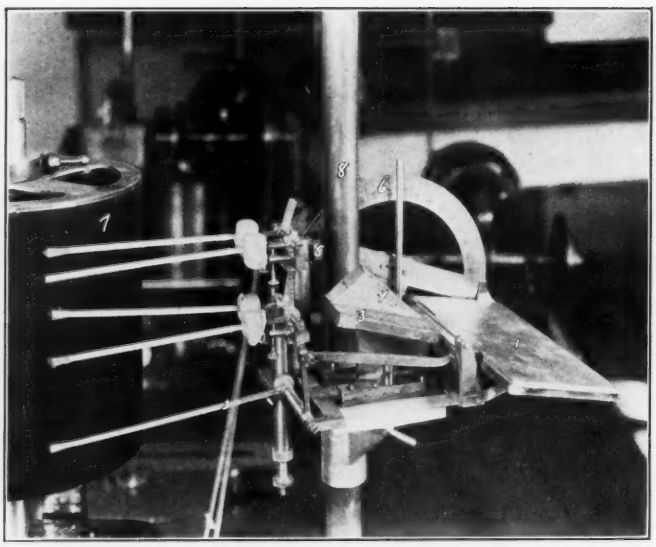

Fig. 1. The Recording Tilt-table.

1. Tilt-table.
2. Recording lever from tilt-table.
3 and 4. Fixed table.
5. Joint for swinging away the two top levers while attaching the threads to the lower levers.
6. Protractor for measuring angle of tilting.
7. Drum.
8. Supporting rod.

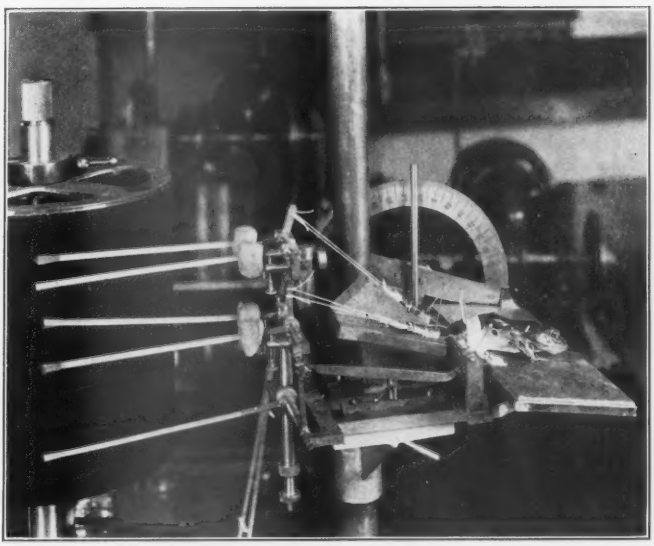

Fig. 2.

1. Decerebrate frog in position on the tilt-table.

2. Restraining band. (Note the two sciatic nerves bridging the axis and running to the two lower leg segments.)

3 and 4. Right and left legs with threads from the flexor and extensor muscle groups of the ankles to the recording levers.

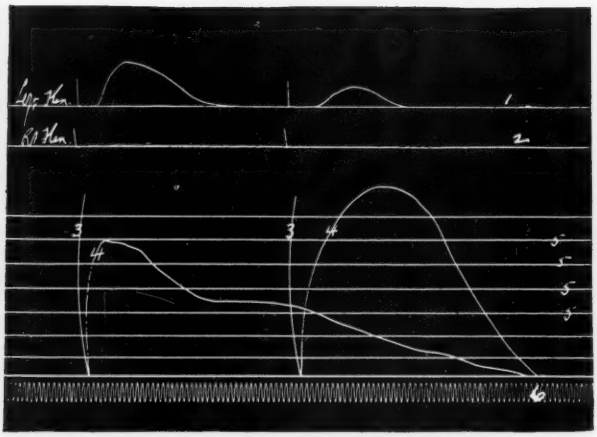

Fig. 3.

Tracing from frog with the ampulla of the left posterior vertical semicircular canal destroyed. Response to backward tilting when the long axis of the frog's body is at right angles to the axis of the table.

1. Flexor muscles of right ankle.
2. Flexor muscles of left ankle.
3. Record of tilt-table when drum at rest.
4. Record of actual tilt of table during experiment.
5. Each line denotes 10 degrees of tilting.
6. Time tracing. (Note the marked response from the right flexor muscles.)

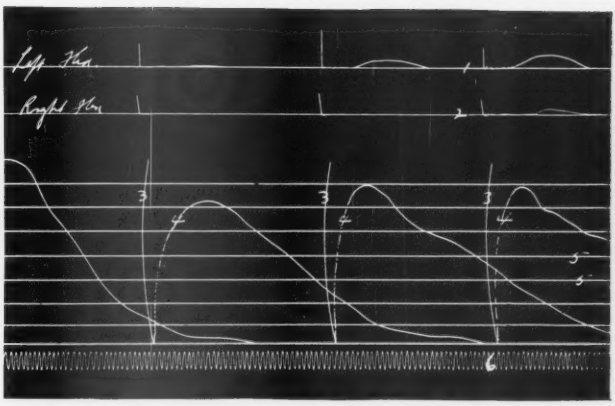

Fig. 4. Backward tilting with body component slewed to left so that the tilting is in the plane of the destroyed left posterior vertical semicircular canal. (Significance of numbering as in Fig. 3.) Note the absent or only very weak response to tilting so extreme as to jar the apparatus.

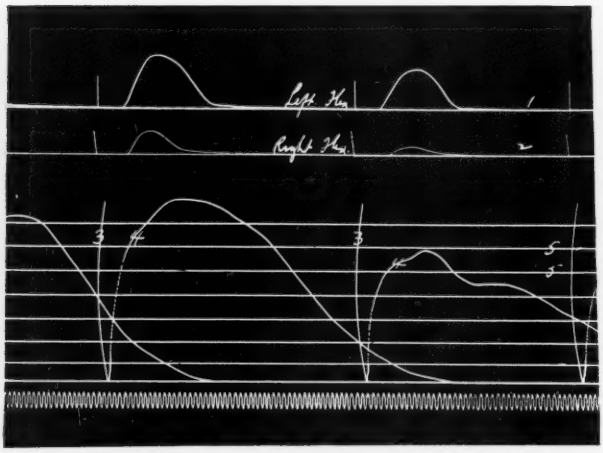

Fig. 5. Frog slewed to the right so that the backward tilting is in the plane of the intact right posterior vertical canal (the significance of the numbering is the same as in Fig. 3). Note the very marked response of the flexors of both limbs though chiefly to the right flexors to relatively slow tilting.

LXXXIX.

THE USE OF ELECTRICALLY HEATED BOUGIES IN THE TREATMENT OF POSTDIPHTHERITIC CICATRICIAL STENOSIS OF THE LARYNX.

By W. H. Johnston, M. D.,

St. Louis.

There are three factors to be considered in the etiology of this type of cicatricial stenosis of the larynx:

1. Intubation.
2. Tracheotomy.
3. Diphtheria.

Intubation not properly done may injure the mucous membrane and cartilage, or the intubation tube may actually be forced into the tissues of the neck. The intubation tube may be left in position for too long a time and may cause necrosis of the cartilage. A poorly fitting tube may bring about this same condition. Jackson gives three weeks as the time that a tube may safely be left in place. At the end of three weeks a tracheotomy should at least be considered.

The most common error is a poorly placed tracheotomy, many times in the cricothyroid membrane or just below. There should be one tracheal ring, or better still, two tracheal rings left intact above the opening made for the tube.

Diphtheria is a necrotic process and must result in the formation of a certain amount of scar tissue and later a stenosis. Even though a perfect intubation and tracheotomy has been done a stricture may result from the fibrosis following a necrosis.

For many years the urologists have been using heat to aid them in the treatment of strictures of the urethra. The heat was applied by various methods, including the electrically heated bougies.

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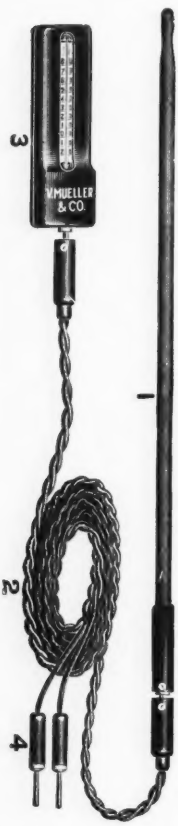
*From the Department of Otolaryngology of Washington University School of Medicine.

In 1921, Dr. L. W. Dean reported his results in the treatment of cicatricial stenosis of the esophagus with electrically heated bougies. It hastened the dilating process by causing a hyperemia, increase in secretion and a moderate edema. A marked edema had to be avoided in the esophagus, as the result would be a temporary closure of the lumen so that no fluids could be taken. This same objection was present in the use of the heated bougies in the partially closed urethra. The bougie was heated to 40° C. and left in place for thirty minutes and was followed immediately by the usual dilating process.



At the St. Louis Isolation Hospital there are at all times many cases with varying degrees of laryngeal stenosis. These are being treated by dilatation with metal dilators under direct inspection. In July, 1929, there were two cases in which this method of treatment had been carried on for two or three years without much improvement. They were referred to this department for more radical treatment, and at the suggestion of Dr. L. W. Dean it was decided to try the electrically heated bougies before any other procedure was started.

Case 1.—C. L., age six and one-half years, white, male. Entered the Isolation Hospital on May 29, 1925. He had been ill for a few days with a sore throat and was having difficulty in breathing. A diagnosis of laryngeal diphtheria was made and he was intubated at once. He was reintubated seven times, up to June 5th, at which time an emergency tracheotomy had to be done. The tube was left in the trachea until December 12th. At this time it was removed for cleansing and could not be reinserted. The larynx seemed to be open and the wound was allowed to close. The larynx had been dilated by direct method both before and after the tube was removed.

In spite of this, he had to be intubated sixteen times, up to the 8th of February, 1926, at which time another tracheotomy had to be done.

Since the above date the trachea tube has remained in place and the larynx has been dilated regularly for more than three years with very little improvement. At the time of transfer he had a marked stenosis, and very little air was passing through the larynx. It was impossible to close the tube for any length of time.

He entered the Children's Hospital on July 25, 1929. The general examination was negative except an enlargement of the heart and an irregularity of the beat. The diagnosis was chronic myocarditis and cicatricial stenosis of the larynx. Under direct inspection a No. 20 Jackson dilator was passed into the larynx. This boy remained in the hospital for two weeks and had the larynx dilated with the heated bougie and metal dilators five times. There was considerable improvement, but he was taken home without permission. It was possible to pass a No. 28 dilator the last time he was treated.

Case 2.—R. S., age five years, white, male. Entered the Isolation Hospital on May 31, 1926, the complaint being difficulty in breathing. The history was given that the patient was just recovering from scarlet fever and three days before entrance to the hospital started to have difficulty in breathing. When examined he had marked retraction and was cyanotic. Examination at this time was otherwise essentially negative. There was no visible membrane in the throat. The patient was intubated immediately and it was found that there was considerable edema of the epiglottis and arytenoids. He was immediately given 20,000 units of diphtheria antitoxin. Cultures from the larynx were positive for diphtheria. He was intubated eight times but was unable to retain the tube. A low tracheotomy was performed on June 10, 1926. One month later laryngeal dilatations were started by the direct method. These dilatations were continued for approximately three years with only moderate improvement. He is unable to have the trachea tube stopped up.

With the exception of the laryngeal stenosis and a chronic myocarditis, the general examination was essentially negative. The tonsils were quite large and chronically inflamed. He was

referred to this department for more radical treatment and, as in the previous case, it was decided to first try dilatation with the assistance of the heated bougies. We first dilated three times a week and found that this was too often. He did not have time to recover from the previous reaction at the time of the next treatment. Since this observation was made we have been dilating twice a week. At the first examination we could pass a No. 18 dilator and at the present time we can easily pass a No. 30. We found that a dilator passed before the heat was applied would pass much more readily after the heated bougie was left in place for from ten to fifteen minutes at a temperature of 50° C. His voice, which was only a whisper at first, can now be heard for more than 100 feet. The tube can now be closed for a time, and we feel that with less frequent dilatations and with the natural growth of the larynx the boy will get ample breathing space.

TECHNIC AND DIFFICULTIES ENCOUNTERED IN THE USE OF THE HEATED BOUGIE.

On account of the lack of rigidity in the shank of the bougies it was difficult to hold them in place for the desired time. This has been overcome by having the bougies made with a rigid shank that extends to within two and one-half inches from the tip. To hold the laryngoscope in place for ten to fifteen minutes is, to say the least, very tiresome and we hope to overcome this by using the suspension apparatus. We have kept the temperature at about 50° C. because it was almost impossible to hold the bougie in place for thirty minutes, hence the increase in temperature for the shorter period of time. There is not the objection to edema in the larynx where the tube is in place that there was in treating the esophageal strictures.

The current is regulated by a Wappler current controller, and there is a thermometer in the circuit so that the bougie can be kept at a constant temperature throughout the treatment. The child is wrapped in a sheet, a pillow or sandbag is placed under the shoulders, and no anesthetic is used. A small sized metal dilator is first passed and then the heated bougie is inserted and left in place for fifteen minutes or longer if possible. We then pass successively larger metal dilators under direct inspection, not using enough force to cause any injury.

The bougies are manufactured by V. Mueller and Company, Chicago, in six sizes: 10, 14, 18, 22, 26, and 30.

CONCLUSIONS.

The final result by this or any dilating method will depend on the integrity of the cartilage framework of the larynx, especially the cricoid. From the observations made on these two cases we feel that this combination of heat and metal dilators should be given a trial before more radical and tedious methods, such as laryngostomy and skin grafting, are started. Dr. Jackson feels that direct laryngoscope dilatation is the most valuable method we have of treating laryngeal stenosis. We feel that with the addition of the heated bougie the method will be still more valuable. Results cannot be obtained in a week or month by this or any other method, but by persistent, painstaking attention, we will ultimately be rewarded.

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EUCLID AND KINGSHIGHWAY.

XC.

NONSURGICAL TREATMENT OF CHRONIC MIDDLE EAR SUPPURATION, BASED UPON TWENTY-FIVE YEARS' EXPERIENCE.*

By Joseph C. Beck, M. D.,

Chicago.

INTRODUCTION.

In presenting this subject, I wish at the outset to say I am not offering any panacea for the cure of this most stubborn disease, nor is it my intention to substitute it for necessary surgery of the middle ear and mastoid. I have, however, had such unusually striking results from the treatment that I am describing that I felt it obligatory to make this report. Surely we are all agreed that even if a radical mastoid operation is well performed, in many instances much remains to be desired in obtaining the cessation of the discharge and a conservation of hearing.

TYPES OF CHRONIC SUPPURATION OF THE MIDDLE EAR.

1. Tubal and central perforations.
2. Marginal or attic perforation.
3. Cholesteatomatous formation in the chronic suppuration.
4. Syphilitic disease with chronic ear suppuration.
5. Tuberculosis with chronic ear discharge.
6. Foreign bodies and chronic ear discharge.
7. Infected neoplasms with chronic ear suppuration.
8. Postoperative persisting and recurring chronic suppuration.

CONDITIONS INFLUENCING THE TREATMENT OF CHRONIC MIDDLE EAR SUPPURATION.

1. Bacteriology.—We find mostly mixed infections of staphylococcus variety, but there is always a great flora of nonpathogenic organisms present.

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*Presented before the Thirty-fifth Annual Meeting of the American Laryngological, Rhinological and Otological Society, Inc., San Francisco, July, 1929.

T. B. or spirocheta pallida are rarely found.

In the presence of cholesteatoma and in the recurrent and persistent desquamation with pus formation in the postoperative cases, especially radicals, there is always a great flora present, but the bacillus foetidus can be rapidly cultivated from these discharges.

Washings and centrifugal sedimentation for presence of bone dust is not practiced very much as to diagnosing necrosis at the present time.

2. Roentgenology.—The examination of the temporal bone gives very little information as to the extent or type of the pathologic process present. It will show the degree of density or fibrosis. It may show fistulous tracts throughout the mastoid at times and in the presence of a large mass of cholesteatoma with a thick matrix. This will also show postoperative cases are very interesting in their roentgenographic study. The opposite mastoid X-rayed will give some idea as to the degree of pneumatization that perhaps was present before suppuration developed the chronic pathologic state (the Wittmacks theory). Foreign bodies or tumors may show in the X-ray.

3. Functional Tests.—Their value as to the treatment, particularly the function of hearing, is of great importance. The vestibular tests in the postoperative cases is of greater importance in the presence of the fistula tests. Suppuration may come from a dead labyrinth.

4. Pathology.—The varieties of the pathologic status mentioned before, as studied under the microscope, add much to the understanding of treating suppuration of the middle ear. I don't mean biopsies of the external, middle ear or mastoid.

5. Histories.—This is particularly true as to the origin of the acute process—that is, whether it followed scarlet fever, measles, influenza or just came in ordinary rhinitis, is of prime importance in the evaluation of the treatment.

6. General Examination.—The knowledge as to the presence of diabetes, chronic nephritis, anemia, tuberculosis, syphilis, are important if they exist in the presence of chronic suppuration.

7. Associated Disease.—The existence of associated diseases of the nose, throat and external ear play a great rôle in the management of chronic middle ear suppuration.

8. Comparisons.—Finally, comparing one's results of cases treated by surgical and nonsurgical methods, these must comprise a large enough number of all types and varieties, and the observation must have been over a long period of time—years. My conclusions are based on such comparisons.

On the surgical side are the following procedures:

(a) Ossiculectomy with and without removal of granulations, polypi and the external attic wall.

(b) Simple mastoid exenteration.

(c) The Stacke, Heath, Bondy, Blackwell and Bárány semiradical operations with additional modifications.

(d) Typical radical mastoid operation.

(e) Radical mastoid plus labyrinth operations and intracranial procedures.

On the nonsurgical side:

On this side of the treatment, I have employed, like most of us, anything that sounded rational and recommended from responsible sources. Nonsurgical treatment of this disease, with the few exceptions of the tubal or central perforation, is always undertaken as a problem, in that the ear may stop discharging and remain permanently healed, or there may be recurrences. An operation may be indicated any time.

I am not able to give any statistical report from my own experience or that from the literature, but I will make this general statement, that I have yet to see one case of chronic suppuration of the middle ear that I treated and continued to observe that developed any of the serious intracranial complications. Furthermore, I have not seen any serious general diseases, such as rheumatism, cardio, vascular, renal, etc., from absorption or metastatic—that is to say, a chronic septic focus. Of course, we do not believe in having our patients go about with a chronic suppuration of the middle ear, especially if associated or suspected of necrosism, yet that oft repeated remark that the ear better have an operation because one never knows when it may explode does not hold so far as my own observation goes. There are always present signs and symptoms in plenty of time to warn one and place the indication for the operations.

Up to quite recently, say three to five years, I have not been very much encouraged in the local treatment of chronic sup-

puration, but since then, and particularly in the last six months, I feel much encouraged.

I know that we all can say it is too early to make any conclusions, but I am compelled to say that never have I employed any treatment that showed such striking results as I see from the use of this treatment that I am about to describe.

Technic.—1. By means of capillary suction (Fig. 1) the secretions, epithelial débris, especially from the attic region, is removed.

2. By means of a powder blower (Fig. 2), which has a definite sized container, this powder (which I shall describe more fully) is insufflated. The treatment is repeated two or three times weekly.

The Powder.—We are all familiar with the insufflation of powdered boracic acid and have found that the caking or hardening of the same, being a hindrance to drainage, thus makes conditions worse rather than better.

On a recent visit of Dr. M. D. Lederman of New York, in Chicago, he called my attention to a preparation of boracic acid powder which contains iodin. This powder, in the presence of secretions, is soluble and gives off free iodin. His experience with this type of chronic suppuration of the middle ear, which has extended over a period of years, was so flattering that I undertook to treat a series of more than thirty cases in private practice. I realize, of course, that this is a small number, but I have found that his statements are absolutely correct as to the value of drying up most of these ears. Again I repeat that it is too early to judge as to the permanency of this cure.

The pharmaceutical name of this powder is "Iodine Dusting Powder" (Dr. N. Sulzberger).

The second type of treatment, also depending upon the liberation of free iodin, I have had much longer experience with, but never as satisfactory. In 1926, in the *Monatschr. für Ohrenheilkunde*, Fotiada described very thoroughly the treatment of chronic suppurative otitis media, including cases of cholesteatoma and tuberculosis. His series was very large and observed for a long time after the treatment. The remedy he employed in the form of instillation he called Calot's Sol. It is made up of the following:

Guaiacol	0.25
Creosote	1.75
Ether	7.50
Iodoform	2.50
Olive oil	18.00

(Do not filter.)

He made careful research studies on the pharmacologic action of these various substances and their specific action on the products of chronic suppuration process of the middle ear, and his article is well worth the time to read. My associate, Dr. Guttman, who published our results with Calot's solution in the *Illinois Medical Journal* in August, 1927, corroborates most of Fotiada's claims.

The great objection to this remedy is the pungent odor of the iodoform and creosote, but this can be disguised.

My conclusions are:

1. That chronic suppuration of the middle ear, when labyrinthian irritation, severe headaches and pains or facial nerve involvements are absent, should be persisted in treatment before an operation or the mastoid is recommended.

2. That suction properly carried out, by means of small canulæ in contradistinction of the mass suction by obstructing the external auditory meatus, to which we object, is of great value.

3. That remedies containing iodin have a very beneficial action on the chronic suppurative process, particularly the iodized boric acid powder.

4. That water, especially introduced by way of external auditory meatus, is additionally harmful to the chronically discharging ears.

5. That all contributory pathology, whether local, as granulations or polypi, nasal and pharyngeal disease, as well as all the general conditions, shall have the necessary attention.

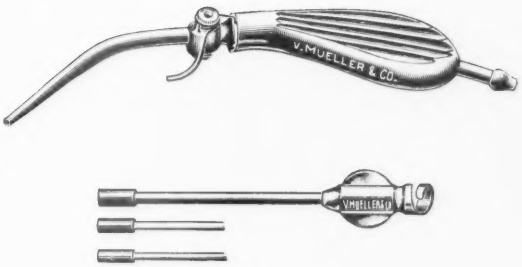


Fig. 1.

Fig. 2.

XCI.

METHOD OF CORRECTING LAX, BAGGY SEPTA FOLLOWING SUBMUCOUS RESECTION.

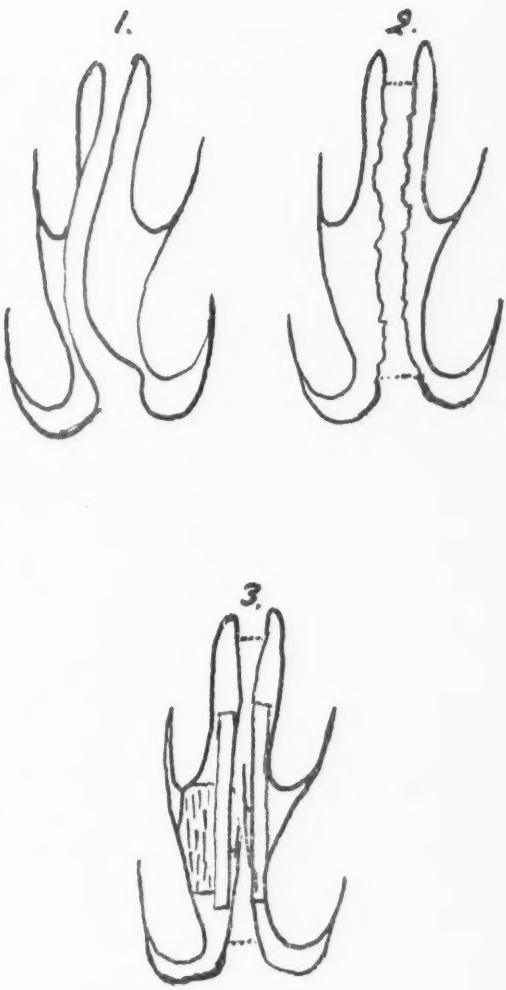
By John A. Pratt, M. D.,

Minneapolis.

Practically all operators who perform submucous resections of the nasal septum find that after this operation in medium and high degree deflections the mucous membrane is very lax and baggy. This is due to the excess membrane necessary to cover the medium and high degree deflections. The blockage is apt to remain on one side, and the patient will complain, not only of the blockage but also of the flapping of the membrane.

For many years we have used no packing following a submucous resection, but placed a piece of dental sheet wax on each side of the membrane. If a Simpson splint is placed between the lateral wall and the dental sheet wax on the convex side of the deflection the pressure will cause an overlapping of the excess mucous membrane and the raw surfaces will seal together, thus shortening the membrane. The Simpson splint is left in position for twenty-four hours and the dental sheet wax for forty-eight hours.

Cut No. 1 shows a high degree deflection; No. 2, the lax membrane, and No. 3 the dental sheet wax splints and the Simpson splint in position and how the flap overlaps.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XCII.

TWO INTERESTING FOREIGN BODY CASES OF THE MASTOID AND THE NOSE.

By Edwin P. Longaker, M. D.,

Philadelphia.

The occurrence of foreign bodies in the nose and external auditory canal is not at all uncommon, especially among children. The objects found are so varied as to be almost without limit.

F. D. Bana[1] reports a series of 21 cases treated in the English Hospital in Bombay. In only one of these cases, that of a stone in the ear canal, was it necessary to cut the membrane lining the canal in order to get behind the foreign body, which measured 4 by 6 mm. Previous manipulations had only served to push it deeper into the canal and had wedged it crosswise.

C. B. Camerer[2] reports a case of a seaman who had a piece of cork in the nose for 17 years; during this time it had adhered to the septum well back in the nares. When removed it contained calcareous deposits and had given symptoms of obstruction, but the report does not state that there was any sinus involvement.

I. W. Voorhees[3] reports a case of a bolt ½ inch by 2⅛ inches, which had been in the nose of a negro for 17 years. This patient came for treatment because of foul discharge. Chronic sinus involvement was present.

C. W. Theisen[4] reports the removal of a rhinestone from the middle ear of a 5-year-old boy, via a posterior incision. Part of the posterior canal wall had to be removed in order to get the foreign body. An unsuccessful attempt at removal had been made before he saw the boy.

E. H. R. Altounyan[5] removed a coin 1.5 cm. in diameter which had been in the nares ten years. It produced chronic maxillary sinusitis.

Wm. P. Kennedy[6] saw a case of 36 years' duration, an old dry kernel of rice, encapsulated, accompanied by cough, which disappeared following removal.

C. J. L. Wells[7] reports another of 33 years' duration.

Undoubtedly many more similar interesting cases have not been reported. The two cases which I would like to report this evening seem to me to have several interesting features.

The first is that of J. D., a boy of 11 years, who was seen by Dr. J. R. Davies in his office on February 14, 1927. The patient was admitted to Dr. Packard's service at the Pennsylvania Hospital the same day.

C. C.—Swelling behind and above right ear.

H. P. I.—The onset dates from 1922, five years ago, at which time the patient put a glass button in his ear. Three physicians saw him at the time and attempted unsuccessfully to remove it. Four X-rays were taken but none disclosed the foreign body, and three more X-rays were taken a year later. The boy does not remember whether subsequent attempts were made to find the foreign body. The ear discharged for two years—that is, until 1924. In 1925, a swelling behind the ear was incised, from which much pus was obtained. Later, following a recurrence, the swelling was lanced again. In 1926, after trauma caused by a snowball, two furuncles developed in the external auditory canal. On February 7, 1927, the patient was pushed against a clothes hanger, since which time he dates this swelling.

Previous Medical History.—Measles and whooping cough.

Family History.—Mother died when this child was born.

Physical Examination.—Behind the right auricle and extending above it, well around to the front there is a large fluctuating swelling. The posterior canal wall also fluctuates. There is no discharge in the canal. The membrana tympani has a fair sized perforation. The mastoid is tender. There is marked adenopathy of the right cervical region. Tonsils enlarged; other organs negative. No X-ray was taken before the operation.

Operative Procedure.—On the day of admittance, under ether anesthesia, the usual mastoid incision was made, but extending up a little higher. This opened a large superficial collection of pus, which extended above and in front of the auricle and was also connected with the fluctuating mass in the posterior canal, it having burrowed between the posterior

wall and the membrane lining the canal. Close behind the external canal, running parallel with it, there was a tract nearly as wide as the external canal; connecting the two at a depth of ½ inch or ¾ inch was a thick fibrous strand. At this level, attached to the posterior wall, and lying between it and the membrane lining the canal there was found a ball of cotton the size of a pea. At the bottom of the deep tract the probe touched a hard foreign body, which proved to be a piece of the glass button the size of a split pea. This lay about at the level of the tympanic membrane. There was marked facial twitching while grasping and lifting it out; the search was continued but soon stopped because of the severe twitching. A small part of the posterior canal wall, which had some fibrous tissue in it, where the cotton lay, was removed. The fistulous tract was curetted, the remainder of the mastoid appeared normal and was not opened. The wound was closed with iodoform gauze in the large pus pocket, also in the tract and in the external auditory canal. The wound healed in two weeks; the ear discharged for six weeks, since which time it has remained dry, with, however, great impairment of hearing, which had been present for several years.

An X-ray, taken by Dr. Bowen after the removal of the foreign bodies, reported as follows: "There is unquestionably a mastoiditis on the right side. We are unable to find any evidence of the foreign body which was found at operation."

The second case is that of C. L., a boy of five years. Admitted to Dr. Eve's service at the Bryn Mawr Hospital on July 8, 1927, with a complaint of bleeding from his right nostril.

H. P. I.—On July 3, the boy put a Fourth of July "snake" in his nose; this resembles a nasal splint, being flat, but is much smaller. The patient was seen by a physician the same day, who attempted to remove the foreign body but without success The physician told the boy's father that the foreign body would move back into the throat and be coughed out. The patient appeared at the accident ward on July 7, 1927, where the intern attempted removal of the foreign body and incised an abscess in the hard palate. Dr. Hughes saw the patient the next day and asked me to treat him. On examination the boy was found to have a mucopurulent and bloody discharge

from the right anterior nares, the whole side being obstructed with it. There was tenderness over the right maxillary sinus and a discharging abscess in the hard palate. A fluoroscopic examination showed the presence of a foreign body. An attempt was made to remove it while working under the fluoroscope but failed because of struggling of the patient and fear of pushing the foreign body into the pharynx and having it swallowed. An X-ray picture was then taken by Dr. G. U. Pillmore, who reported as follows: "There is a foreign body in the lower part of the right nares about 1.2 cm. long and several mm. thick. It lies in the floor of the nares, close to the posterior nares. The long axis is in the anterior posterior position. The right antrum is completely occluded of normal air density, and the same is true of the right ethmoidal group of cells."

The following day, July 9, 1927, under ether anesthesia, the foreign body was removed. It was tightly wedged between the septum and the right inferior turbinate. There was necrotic bone in the floor of the nose, which was curetted. Part of the inferior and middle turbinate were soft and friable. The abscess in the hard palate communicated with the floor of the nose. The right maxillary sinus was irrigated of purulent material; the opening enlarged with a Wilhelminski trocar. The friable parts of the inferior and middle turbinates were removed. Culture of the pus was negative for Klebs-Loeffler bacillus but showed groups of cocci. An X-ray taken two days later reports: "No foreign body, with much better aeration of the ethmoid and occlusion of the right antrum not so complete, suggesting that a portion of the fluid has been drained from this region."

The boy was treated a few times. The antrum was not irrigated following the operation. The abscess closed in two weeks. The nose rapidly decreased its discharge, and when seen in December, 1927, five months after the operation, showed no evidence of sinus involvement.

The most frequent cause of failure to remove foreign bodies is the struggilng of a frightened child. If the patients will not remain quiet, and thus block all our efforts at removal of the foreign body, they should be anesthetized. In this way we

can work with perfect ease and with no hindrance from the patient.

The glass button in the ear case was very likely broken in the early attempts to locate it, and the remainder pushed through the tympanic membrane to lie in the region of the facial nerve. Likewise the foreign body in the nose was in all probability pushed deeper into the nares during the manipulations. Here a prompt X-ray and anesthesia would have prevented the acute sinusitis and necrosis caused by some intensely irritating chemical in a foreign body; although no analysis was made it was probably phosphorus.

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1806 SPRUCE STREET.

XCIII.

FIVE LECTURES ON THE PHYSIOLOGY OF THE EAR.*

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LECTURE 1.

THE PHYSIOLOGY OF THE COCHLEA WITH SOME REMARKS ABOUT THE CLINICAL TESTS FOR HEARING.

THE INTERNAL EAR.

To understand the physiology of the internal ear more clearly, we must first refresh our memory concerning the anatomy of the organ. It is made up of the cochlea, or sound perception mechanism, and the vestibular portion, which is the balancing mechanism. The internal ear, therefore, is concerned with sound vibrations, head positions and head movements.

The internal ear is a very small, delicate, membranous sense organ. It is embedded in fluid and surrounded by a very dense bony capsule—some of the densest bone in the body. The fluid cushion is called the perilymph. The organ is anchored to the bony walls by fibrous septa. In this dense case one might say the membranous internal ear is floating in a water bath. Its contact with the outside must come as a vibration of this surrounding fluid or else through the nervous connections to the end organ. It is thus protected from severe jarring, etc. The internal ear, as well as being surrounded by

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fluid, is filled with a fluid called the endolymph. It is divided into an upper and lower part by the limiting membrane of de Burlet.

THE ANATOMY OF THE COCHLEA.

To understand the anatomy of the anterior portion of the internal ear, the sound perceiving mechanism, or cochlea, it is well to understand the anatomic mechanism by which the sound is ordinarily transmitted to the cochlea. This sound conducting mechanism consists of the external and the middle ear. The external ear consists of the auricle, which in some types of animals actually serves the purpose of collecting the sound waves and condenses them through the external canal to the drum membrane. Embedded in the drum membrane is the long handle of the malleus, the head of which articulates in the attic with the body of the incus. The long process of the incus, which is shorter than the long process of the malleus, in turn articulates with the head of the stapes. The footplate of the stapes fills the oval window, to the edges of which it is attached by an annular ligament. The articulation of these three bones is so arranged that when the drum membrane is moved in or out by a sound wave, the footplate of the stapes moves in the same sense—that is, when the drum moves in, the footplate of the stapes moves in. However, owing to a difference in the length of the bones and the arrangement of the leverage, the amplitude of the movement is decreased and the intensity increased, so that the sound wave transmitted to the cochlea through the oval window has a smaller amplitude but an increased intensity. For the normal working of the drum membrane, it is necessary to have atmospheric pressure on both sides. The air reaches the drum externally through the external canal. Atmospheric pressure is maintained on the inner side of the drum membrane—in the middle ear—through the eustachian tube. This tube when at rest is generally believed to be closed in its middle third. However, during the reflex acts of swallowing and yawning, etc., the tube is opened so that the pressure in the middle ear becomes atmospheric pressure. The opening and closing of the eustachian tube is due to the fact that some of the muscles concerned in the movements of the soft palate during active

swallowing are attached to or lie in very close proximity to the walls of the eustachian tube. The chief muscles concerned are the tensor palati and the levator palati and the salpingo-pharyngeus. Some of the fibers of the tensor palati take origin from the lateral cartilaginous plate of the eustachian tube. These fibers are sometimes called the dilator tubæ muscle. The tendon of the tensor tympani passes around the hook of the pterygoid plate and receives a certain amount of fixation at that point so that when the muscle contracts, the lateral wall of the eustachian tube is pulled downwards and forwards, thus opening the lumen of the tube. The small muscle, the salpingo-pharyngeus, takes origin from the medial plate of the eustachian tube and runs downwards and is inserted into the pharyngeal wall. It pulls the medial plate of the tube downwards and backwards, also tending to open the lumen of the tube. The part played by the levator palati in the opening of the eustachian tube is an indirect one. It has no direct attachment to the tube, but the body of the muscle lies along the floor of the tube. When the muscle contracts, the belly of the muscle expands, pushing the floor of the eustachian tube up so that the lumen, which when closed is slitlike, is thereby opened. The importance of the ventilation of the middle ear is very generally known. It is a common experience to have a blocked, stuffy feeling in the ear, which is suddenly relieved by the act of swallowing or yawning. The drum membrane, which was momentarily retracted, owing to absorption of the air in the middle ear, creating a negative pressure, is immediately relieved by the reflex opening of the eustachian tube during the act of swallowing, which allows entrance of air from the throat, reestablishing atmospheric pressure on both sides of the drum.

From the footplate of the stapes the sound waves enter the cochlea. The membranous cochlea consists of a tube coiled on itself two and a half times around a relatively hollow bony core, the modiolus. This tube, or cochlear duct, is of course encased in the dense bony covering, which is coiled to resemble a shell, hence the name cochlea. The perilymph is arranged in two chambers or tubes, one above the cochlear duct, called the scala vestibuli, and one below the cochlear duct, the scala tympani. These tubes or chambers of

perilymph join at the top of the cochlea, the helicotrema. The scala vestibuli begins at the oval window, in which is the footplate of the stapes. It joins the scala tympani at the helicotrema. The scala tympani extends down from the helicotrema to end at the round window, which is closed by a membrane. There is a canal which leads from the floor of the scala tympani to open into the cranial cavity near the jugular foramen, into the subarachnoid space. This canal, called the aqueductus cochleæ, is filled with areolar tissue. Through this canal there is supposed to be a connection of the perilymph with the cerebrospinal fluid. Some surgeons advocate puncturing the round window membrane as a method of gradually relieving increased intracranial pressure by allowing a flow of the cerebrospinal fluid through the aqueductus cochleæ into the scala tympani and through the round window into the middle ear. The puncturing of the round window membrane would, of course, allow the escape of perilymph. In the reported cases in humans, the detailed hearing tests are not given, but it is stated that there is some interference with hearing. If Wilkinson and Gray are correct, there should be a decided interference until the wound in the round window membrane heals, because fluid leading of fibers of the basilar membrane is removed. In a series of rabbits, I had occasion to puncture the round window to allow the perilymph to escape. In these cases, of course, we were not in a position to examine the hearing of these rabbits. It would require extensive preliminary training of the animals. It did not change any of the known labyrinthine reflexes except for a slight homolateral diminution of tonus.

A cross section from above down through the cochlea shows the modiolus in the center, with the cochlear duct with its scala at slightly different levels on each side. On examining a cross section one sees coming out from the modiolus a bony shelf or lamina to which the cochlear duct is attached internally. The outer side of the duct is anchored to the external wall by a ligamentous structure, which follows it from the basal to the top coil—the spiral ligament.

Gray has drawn attention to the fact that at the base of the cochlea this ligament is extremely thick and dense, whereas in the apical coil it is a very thin structure. The cochlear

duct is closed above by a thin, loose membrane, which is attached internally to the upper surface of the bony lamina and externally high up on the lateral bony wall. It is called Reisner's membrane. The floor of the duct, which extends from the bony lamina to the spiral ligament, is called the basement membrane. It is a very firm, tense band of laterally placed fibers, and it is these fibers which are generally accepted to be the vibrating or resonating elements of the cochlea. Resting on this basement membrane at its inner attachment is the actual nervous end organ of hearing—Corti's organ, which consists simply of several rows of nervous hair cells, which are held together by longer and firmer supporting cells, which rest directly upon the basement membrane. The tufts of the hair cells project just above the level of the top of the supporting cells of Deiter. Over the point of attachment of the basement membrane to the bony lamina, two of the supporting cells are modified to form rod-shaped structures called the rods of Corti. These rods are widely apart at their attachment to the basement membrane, one rod resting on the bony lamina, the other on the basement membrane and above they are in contact. By this arrangement a tunnel is formed which extends from the base to the apex of the cochlear duct. The nerve fibers from the outer rows of hair cells pass across this tunnel on their way through the bony lamina, and by this tunnel arrangement are supposed to receive protection during vibrations of the basement membrane. The hair cells are arranged in three rows external to Corti's rods, and one row internal to Corti's rods. The nerves pass from the base of these cells into canals in the bony lamina, through which they enter the modiolus, where they join the spiral ganglia, and then pass into the internal auditory meatus, where they form part of the eighth nerve together with the vestibular branches. Just above the level of the hair cells of Corti's organ is the tectorial membrane. It is attached at its inner end to the upper surface of the bony lamina. Opinion has differed widely as to the actual histologic structure of this membrane. Some believe it to be fibrous and reedlike. It evidently depends upon the histologic technic used in the preparation of the sections. Gray believes that normally it is a thick gelatinous membrane over-

lying Corti's organ, attached internally to the bony lamina and externally to the outer edge of Corti's organ. He believes that the hair cells project into this gelatinous membrane and that it is somewhat analogous to the gelatinous cupula which overlies the cristæ in the ampullæ of the semicircular canals. At the base of the cochlea the basement membrane is very narrow. However, it becomes progressively wider towards the apex, till at the top coil the individual fibers are about three times as long as they are at the base.

As was pointed out before, the spiral ligament to which it is attached externally is very much more dense at the base of the cochlea than it is at the apex. We see, therefore, that the fibers of the basement membrane are shorter at the base of the cochlea and held more tense by the spiral ligament. At the apex the fibers are longer and are held less tense by the thinner, weaker spiral ligament. The fibers, therefore, vary for length and tension. All these structures are, of course, immersed in the endolymph which fills the cochlear duct. Immediately below the basement membrane is the perilymph in the scala tympani. Immediately above Reisner's membrane is the fluid in the scala vestibuli. From the lower end of the cochlear duct is a very small canal connecting it with the saccular chamber. This is called the ductus reuniens.

COCHLEAR NERVE.

The nerve fibers from the cochlea, after leaving the modiolus, join with the fibers from the vestibular portion of the internal ear to form the eighth nerve. At the medulla the eighth nerve again separates into its vestibular and cochlear portions. After entering the medulla the cochlear fibers end about the cochlear nuclei, which are in close relation to the inferior cerebellar peduncle. From these nuclei some of the fibers run dorsally across the floor of the fourth ventricle—the striæ medullaris—to cross to the lateral fillet of the opposite side. Other fibers run ventrally, as the corpus trapezoideum, and either directly or after a new relay cross to the opposite side and ascend in the lateral fillet to the inferior corpora quadrigemina and the medial geniculate body. Some fibers pass directly to the lateral fillet of the same side; some fibers pass to the nuclei for the nerves of the external

ocular muscles. It is through these tracts that associated movements of the eyes take place in response to sound. From the inferior corpora quadrigemina and medial geniculate body fibers pass to the auditory center in the cortex of the temporal lobe. Commissural fibers connect the inferior corpora quadrigemina and medial geniculate portions of the two sides.

Each cochlea is connected with both temporal lobes, though mainly with the temporal lobe of the opposite side. It is evident, therefore, that a lesion of one temporal lobe should not cause deafness. This was well shown in a series of six cases reported by Dande, where he removed the whole right temporal lobe and in no case was there impairment of hearing. In one case, where an audiogram was done, the hearing was equal in both ears and practically normal. A unilateral lesion above the corpus trapezoideum would not cause deafness, but there would probably be an interference with the auditory reflexes to the eyes and head for eye movements and head movements in response to sound falling on the ear on the side of the lesion.

THE PHYSIOLOGY OF THE COCHLEA.

The cochlea is the nervous end organ for hearing. Sound which reaches the drum membrane is transmitted by the ossicles, the sound vibration being decreased in amplitude and increased in intensity, so that the impulse imparted by the footplate of the stapes to the fluid in the scala vestibuli has a smaller amplitude but an increased intensity. There has been much difference of opinion as to how the cochlea interprets the sound wave which is carried to it. There are two main schools of thought:

Telephone Theory.—The telephone theory was first put forward by Rutherford, who believes that the cochlea receives the sound vibration, which is transmitted directly to the nerve and carried to the brain, the analysis of the sound taking place in the auditory center in the brain.

Resonance Theory.—The second theory is the resonance theory, first introduced by Cotugno, and more fully elucidated by Helmholtz. It is believed that the cochlea consists of a series of resonating elements by which the complex sound vibrations are broken up and analyzed into their simple constit-

uent harmonic components, so that the stimuli transmitted to the nerve fibers are carried to the brain under the same conditions as ordinary stimuli of touch and taste. This latter theory is the most generally accepted today.

There are many technical objections raised against the telephone theory. It will suffice to mention the one which seems the most convincing. If the complex sound vibration is received by the cochlea and transmitted, telephone-like, to the nerve, it would mean that the eighth nerve was transmitting to the brain vibrations of a frequency as high as ten to twenty thousand a second. It is known, however, that a nerve fiber will not conduct more than 1500 impulses a second.

The resonance theory presumes that the cochlea acts like a resonator in the same way as an open piano. When a note is sung into a piano the string corresponding to the note undergoes sympathetic vibration.

Opinion is divided as to which part of the cochlea is the actual resonating element. There are two main theories.

Tectorial Membrane as a Vibrator.—A small group, including Shambaugh, believe that the tectorial membrane is the vibrating factor. They consider the basement membrane, encumbered by the organ of Corti, unsuitable for vibration.

They point to the spiral artery, the course of which lies under the basement membrane, as indicating that the basement membrane would be affected by any change of blood pressure; therefore, incapable of acting as a resonator. They consider the tectorial membrane as being a reedlike structure attached along its inner margin to the upper surface of the bony lamina. It is wider at the apex than at the base, therefore progressively differentiated in width from base to apex.

The Basement Membrane as the Vibrator.—The more generally accepted idea, and that which is supported by Wilkinson and Gray, is that the basement membrane contains the resonating elements of the cochlea. Gray points out that the histologic appearance of the tectorial membrane varies greatly with the method used in the preparation of the specimen. He believes that when properly prepared the tectorial membrane is shown to be a thick gelatinous membrane unsuitable to act as a resonator and more similar to the gelatinous cupula of the cristæ of the semicircular canals. He considers that the

hair cells of Corti's organ are actually embedded in the under surface of the tectorial membrane and that the tectorial membrane is loosely attached to the outer edge of Corti's organ, which would also interfere with its reedlike vibration. On the other hand, it is pointed out that the structure of the basement membrane is in keeping with the principle of a stringed resonator. The frequency or pitch of a vibrating string depends upon three factors—the length, the tension, and the mass or loading of the string. A variation in any one of these three factors will alter the frequency or pitch of the vibration. Therefore, a series of resonating strings to cover a wide range of frequencies must vary all three factors.

The basement membrane consists of a series of fibers, side by side, stretching from the bony lamina externally to the spiral ligament. At the base of the cochlea the fibers are short and the spiral ligament is dense and bulky. At the apex of the cochlea the fibers of the basement membrane are about three times as long as they are at the base, and at the apex the spiral ligament is a very thin, delicate structure. In between these extremes there is a gradual differentiation. Thus it is seen that the fibers of the basement membrane are varied for length and tension. The fact that the organ of Corti rests upon the basement membrane is considered by Wilkinson and Gray as added argument in favor of the basement membrane being the vibrating element. With every movement of a fiber, or rather a sector of the basement membrane, the superimposed hair cells are moved against the relatively inert tectorial membrane. This causes a nerve impulse to be sent out to the brain. They point out that the spiral artery of the basement membrane is so close to the inner attachment of the basement membrane that any changes in the artery itself would not alter or interfere with the vibrations of the basement membrane.

It has already been mentioned that the fibers of the basement membrane vary for length and tension. It has been computed by careful observers that the difference in length of the basilar fibers would be sufficient to account for a variation in hearing of about one and three-quarter octaves. The difference in tension on the fibers, one of the most important factors, would account for a range of hearing of about seven octaves. This is a total of about nine octaves. However, the wide range

of human hearing covers eleven octaves. The remaining two octaves must be accounted for by the difference in mass or loading of the fibers. In the basement membrane, however, there is no difference in the actual cross section or mass of the fibers of the apex or the basal turn of the cochlea. In the case of the piano, the loading of the fiber is accomplished by winding the steel wire with very fine copper wire, which is pliable and very closely adherent, so that it will not interfere with the natural vibration of the steel string. In the case of the cochlea, Wilkinson and Gray point out that the difference in mass or loading of the fiber is accomplished by the fluid in the scala vestibuli and scala tympani rather than by a change in the actual bulk in the individual fibers. In the cochlea the long fibers are situated at the apex farthest away from the oval and round windows, so that the columns of fluid from these fibers to the windows are long. The distance a wave must travel from the footplate of the stapes through the scala vestibuli to the apex of the cochlea is very great, as compared with the short distance or short column of fluid through which a wave must pass to reach the short tense fibers at the base of the cochlea. This difference is the difference in the fluid load on the basal and apical fibers. They further point out that as the loading of the fibers is accomplished by the fluid in the scalæ, it is advantageous to have the basilar fibers bound together in the form of a membrane so that a sector of the membrane vibrates at any one time rather than that the individual fibers should vibrate separately. This fluid load accounts for a range of hearing of about two octaves. There are, therefore, in the human cochlea all the factors necessary for a stringed resonator. The fibers of the basilar membrane are varied for length, tension and load, and it has been computed mathematically that these variations in the small human cochlea are sufficient to account for the wide range of hearing of ten or eleven octaves.

To subject their ideas to experimental proof, Wilkinson and Gray constructed a model of the basilar membrane. It was built as small and as closely as possible in the same proportion as the human basilar membrane. They used fine wire varied for length and tension, and to stimulate the membrane effect they covered the wire with cigarette paper and

formalized gelatin. This membrane was immersed in fluid with a chamber above and a chamber below to represent the scala vestibuli and the scala tympani. These chambers were connected at one end to represent the helicotrema. The helicotrema was discovered to be a very important part of the arrangement. In the first models, it was not sufficiently large so that the vibrations were very considerably interfered with. Different pitched loud tuning forks applied to the stapes of the instrument produced a response at a definite level on the basement membrane. They were also able to get well localized responses analogous to bone conduction by using the louder forks. They found that if the model was used without the fluid in the chambers, there was a difference of nearly three octaves in localization. They also found that the fluid load allowed the use of fibers about ten times as short. This fact was evidently taken advantage of in the construction of the human cochlea.

To summarize briefly, when a sound wave falls upon the drum membrane, it is carried by the malleus and incus, being decreased in amplitude and increased in intensity by them and is imparted by the stapes to the fluid of the scala vestibuli. Depending upon the pitch of the vibration, it is carried to a corresponding fiber or sector of the basilar membrane, which is set in sympathetic vibration, the wave continuing down the scala tympani and expending itself against the round window membrane. The hair cells in Corti's organ resting upon that sector of the basement membrane, which is caused to vibrate, are stimulated by their contact with the relatively immobile tectorial membrane. A nerve impulse, therefore, is sent out from those cells, which travels in the nerve fiber through the bony lamina to the spiral ganglion. Gray believes that the fibers from each hair cell have synapses with more than one ganglion cell, so that there is a certain amount of overlapping. From the ganglion cell, the nerve proceeds through the modiolus to the internal auditory meatus, where it enters the eighth nerve. At the medulla it enters the cochlear nucleus in the region of the inferior cerebellar peduncle. A new relay passes either dorsally through the striæ medullaris or ventrally in the corpus trapezoideum to cross the midline and ascend in the lateral fillet of the opposite side to the inferior corpora quadri-

gemina and medial geniculate body and finally through the auditory radiations to the auditory center in the cortex of the temporosphenoidal lobe, where the nerve impulse is interpreted as a sound of a definite frequency. Some of the fibers ascend to the cortex of the same side. If the sound is transmitted to the cochlea by bone conduction, the longitudinal wave of compression and rarefaction is transmitted to the fluid of the cochlea, and that sector of the basilar membrane with a corresponding periodicity to that of the sound wave is set in motion, and of course the columns of fluid of that sector are also set in motion and the appropriate nerve impulse is transmitted to the brain.

BASIS FOR CLINICAL TESTS OF HEARING.

Deafness may be caused by a lesion in any part of the hearing apparatus, namely, from the external ear to the brain. If the lesion is proximal to the drum membrane, it may be very difficult to diagnose its exact location in the absence of actual acute suppuration. For the sake of convenience, lesions affecting the auditory tracts are considered in two groups. The first includes lesions of the sound conducting mechanism, usually referred to as middle ear deafness. The second includes lesions of the sound receiving apparatus, and are usually referred to as nerve deafness. The sound conducting apparatus consists of the external ear and the middle ear, including the three ossicles and the eustachian tubes. The sound receiving mechanism consists of the cochlea, the eighth nerve and its intracranial connections. The differential diagnosis between these two types of deafness is often very difficult, because so many cases show symptoms common to both classes.

Bone Conduction.—Bone conduction forms the basis for many of the clinical tests which are used to differentiate between conductive and perceptive deafness. There are two types of bone conduction—relative and absolute. Relative bone conduction is tested by applying a sounding tuning fork over the patient's mastoid, and when the patient ceases to hear, the fork is transferred to the mastoid of the examiner. In this way the patient's relative bone conduction is compared with that of the examiner. This is the modified method of Schwabach. It is this type of bone conduction with which the ordinary

otologist is familiar. It is the basis for the Rinne, Weber and Schwabach tests. It is a test for a lesion of the conductive apparatus.

Absolute bone conduction is tested by placing a sounding tuning fork on the mastoid of the patient when both external canals are closed, either by the finger or by pressure on the tragus. The patient's absolute bone conduction is then compared with the absolute bone conduction of the examiner. The closure of the external canal greatly increases the length of time that the fork can be heard on the mastoid, and it eliminates any effect that a lesion of the conductive apparatus might have on the duration of the bone conduction. By this method, bone conduction is never increased above normal. For this reason, absolute bone conduction becomes a test for perceptive deafness. Bone conduction, considered in this connection, has never received general application, and my subsequent remarks all refer to relative bone conduction, or bone conduction as it is generally understood by the average otologist. Before leaving this subject, however, I shall refer to what appears to be a rather valuable suggestion in connection with absolute bone conduction.

The value of testing a patient's relative bone conduction is based upon the fact that when there is a lesion of the sound-conducting apparatus—middle ear type of deafness—there is often an increased hearing for bone conduction in the affected ear, whereas, when there is a lesion of the sound-receiving apparatus—nerve deafness—there is always a diminution of hearing of sound by both air and bone conduction. When there is definitely increased bone conduction in the affected ear (by Schwabach's method), it is diagnostic of a lesion of the sound-conducting apparatus. By definite increase is meant that as compared with a normal ear, the bone conduction in the diseased ear is increased when the fork is applied over the mastoid without occluding the meatus. This does not necessarily mean, as compared with the patient's other ear, that bone conduction is increased in the affected ear, because bone conduction in the other or supposed normal ear may have been decreased from some other cause. This increased bone conduction means increased, as compared with the examiner's

bone conduction. This presupposes that the examiner has previously determined that his own bone conduction is normal, or, if not normal, he knows how much it is increased or decreased from normal, so that due allowance may be made at the time of examination, otherwise the significance of this increased bone conduction is entirely lost.

Unfortunately, of course, many of the cases of middle ear deafness do not show this increased bone conduction; also many early cases of nerve deafness do not show a definite loss of bone conduction. It is in these cases that diagnosis may become very difficult or even impossible for a long period of time.

I know of no satisfactory explanation of the fact that bone conduction may be increased in a lesion of the sound conducting apparatus. Ruttin explains it on the basis that when a sound is conducted to the cochlea by bone conduction, much of the energy is thrown off from the head by the intact ossicles and drum. This may be illustrated by the simple experiment of using a diagnostic tube between two people, inserting one end in the ear of one and the other end in the ear of the other person, then if the handle of a vibrating tuning fork is placed over the mastoid process of one person it can be clearly heard by the other. The sound heard by the second person, according to Ruttin, is thrown off by the intact ossicles and drum of the first person. When there is a lesion of the conducting apparatus—that is, if the ossicles and drum are not vibrating normally, owing to suppuration in the middle ear, etc., they do not throw off energy or sound waves as they would normally, therefore this extra energy is referred back into the cochlea of that side, so that the hearing for bone conduction on that side is increased. This seems a plausible explanation. It is further supported by some experiments carried out by Runge in normal patients. He filled the external canal of one ear with water. Bone conduction was increased on the side where the canal was filled with water. One explanation was that the water exerted pressure on the footplate of the stapes and altered the position of the intralabyrinthine structures. The water may have acted as an obstruction to the ossicles and drum, preventing the throwing off of the extra sound waves, which were again referred back to the cochlea of that side.

Clinical Tests.—Many of the common tests for hearing in daily practice are designed to show the relative condition of the bone conduction as compared with air conduction of sound from a vibrating tuning fork. Normally, a vibrating fork is heard by air conduction long after it ceases to be heard by bone conduction. The Rinne test is based on this fact and consists of comparing a patient's air and bone conduction. The Rinne test is positive when, as is normal, the air conduction is longer than bone conduction. The Rinne test is negative when the vibrating tuning fork is heard by bone conduction after the patient has ceased to hear it by air conduction. This is an abnormal condition. As there may be such a great change in either the bone conduction or the air conduction and yet have this normal ratio of air conduction longer than bone conduction, the Rinne test unaccompanied by other tests may be very misleading.

The comparison of the bone conduction of the two ears is called the Weber test. The handle of a vibrating tuning fork is placed on the vertex. The sound is referred to the ear in which the bone conduction is increased. If the case is one of middle ear deafness, the sound will be referred to the diseased ear. If the condition is nerve deafness, the sound will be referred to the normal ear, because in the case of nerve deafness bone conduction will be decreased in the diseased ear.

The comparing of the patient's bone conduction with that of the examiner's (and it is presumed that the examiner knows his own bone conduction is normal) is the most valuable test of all three. It is called Schwabach's test. As compared with the normal examiner, this test gives the information that the patient's bone conduction is increased or decreased and by how many seconds in each case.

For teaching students, it would seem more important to impress upon them the significance of increased or decreased bone conduction rather than to insist that they remember these three tests which have been given names with their supposed diagnostic significance. In the majority of cases, if the student remembers the name, he has forgotten the significance of the test, or vice versa, whereas if he knew the underlying physiologic principle he could work out the three tests himself.

In the current issue of the Journal of Laryngology and Otology (February, 1929), Clark strongly advocates the use of a test for absolute bone conduction, first suggested by Pomeroy (1882), in preference to the more generally accepted relative bone conduction tests. This test consists of a comparison of the subject's absolute bone conduction (that is, perception of a tuning fork placed on the mastoid, the meatus being closed by the finger), with a normal person's absolute bone conduction. This is a test for the perceptive component of hearing. It is not affected by any lesion of the conductive apparatus, whether it be complete destruction of the drumhead or ossicular chain, etc. Using the 512 fork, the duration of the absolute bone conduction is about half that of normal air conduction for this same fork. If this ABC is shortened, it means nerve deafness, or if it is referred to one side, it means nerve deafness of the other side. If ABC is longer than AC, it means a lesion of the conductive mechanism. If when the fork is removed from the subject's mastoid, it can still be heard by a normal examiner, it means a nerve lesion in the subject.

I have had no personal clinical experience in the use of this test, but, as explained by Clark, it would seem to be a very valuable diagnostic aid in distinguishing conductive from perceptive deafness.

Air Conduction.—Another point that may serve as a differential diagnosis between middle ear and nerve deafness is the fact that in a lesion of the sound conduction apparatus—middle ear deafness—there is a greater loss of hearing for low tones than for high tones. In a lesion of the sound receiving apparatus—nerve deafness—there is supposed to be a greater loss for high tones than for low tones. The loss is more marked from C 54096 and up (Bunch).

It is explained that when the sound conduction apparatus is diseased or interfered with, the low tones are not well transmitted through the drum and ossicles, whereas the high pitched notes of short wave length pass through to the cochlea much more readily. It seems more difficult to understand, on the other hand, why, in a lesion of the sound receiving apparatus —nerve deafness—there should be a greater loss for high tones. This would mean that the lesion is more commonly situated near the basal turn of the cochlea or affects the nerve

fibers and intracranial connections from the basal turn. If the lesion is in any other part of the cochlea, the hearing loss should be greatest for the notes to which the diseased area in the cochlea corresponded. It seems more difficult, therefore, to understand, from a physiologic point of view, why there should be greater loss for high tones in nerve deafness. These facts constitute the main points in the examination of the hearing on which to base a differential diagnosis between lesion of the sound receiving apparatus—nerve deafness—and a lesion of the sound conducting apparatus—middle ear deafness.

Other Factors in Differential Diagnosis.—Of course, many outside factors must also be taken into consideration. For instance, if one suspects a middle ear deafness, the presence of definite nasopharyngeal disease or a history of recurring catarrhal inflammation of the middle ear would render the diagnosis more probable of middle ear deafness. On the other hand, if the deafness is very profound and there is the history that the patient works in a boiler factory or in a paint factory, the probabilities are that the lesion is in the sound receiving apparatus—nerve deafness. If one is suspicious of a lesion of the sound receiving apparatus—nerve deafness—as confirmatory evidence it is very important to determine the condition of the vestibular mechanism, which is very often involved in lesions of the cochlea or its intracranial connections. The cochlea sends fibers to the temporal lobe of each side, but especially to the temporal lobe of the opposite side. A crossing takes place in the medulla just after the fibers leave the cochlear nuclei. A unilateral lesion above this level, therefore, does not cause deafness. This was well illustrated in Dande's series of six cases, where he removed the whole temporal lobe of one side and the hearing remained normal. If there is deafness accompanying a lesion above the corpus trapezoideum it means that the lesion involves the cochlear fibers of both sides or else the deafness is due to some other factor peripheral to the lesion and is probably not connected with it.

Classical Picture of Middle Ear and Nerve Deafnesses.—The classical picture of a lesion of the sound conducting apparatus —middle ear deafness—is a moderate amount of deafness, about 30 to 40 per cent; increased bone conduction; and a loss

of low tones by air conduction. The classical picture of a lesion of the sound receiving apparatus—nerve deafness—is profound deafness, 40 to 60 per cent; decreased relative and absolute bone conduction; and a loss of low and high tones by air conduction, but especially the high tones.

SUMMARY.

The cochlea is the end organ for the perception of sound, which is conveyed to it by the intact drum and ossicles and also through the cranial bones.

The most probable theory of the mechanism of the cochlea is that it acts as a stringed resonator. It fulfills all the requirements physically.

The basilar membrane, which is the most probable vibrating element, consists of a series of laterally placed fibers. Each fiber is varied in length. There is variation in tension of the fibers, owing to the graduation of the spiral ligaments. The loading of the fibers is accomplished by the fluid in the scala vestibuli and scala media. It has been calculated mathematically that there is sufficient variation in these three factors to allow of a perception of sound over a range of about eleven octaves, which is the normal range of human hearing.

The sound, therefore, falling on the cochlea is analyzed into its simple harmonic constituents, which are transmitted to the brain as simple nerve impulses from each corresponding fiber or sector of the basement membrane.

LECTURE 2.

THE PHYSIOLOGY OF THE SACCULE AND SACCUS ENDOLYMPHATICUS.

It would seem proper, before discussing the physiology of any part of the vestibular labyrinth, to briefly review the anatomy of the whole organ in order that we may appreciate the interrelation of the component parts. Then as we take up each part we can again review the detailed anatomy of that particular part.

THE ANATOMY OF THE VESTIBULAR PORTION OF THE LABYRINTH.

The vestibular labyrinth consists of the semicircular canals and the otoliths. It is situated in the pars superior of the

internal ear, all but the saccule, which, together with the cochlea, forms the pars inferior below the limiting membrane of de Burlet. The general function of the labyrinth is to inform the animal of the movements and position of the head in space, so that necessary readjustments of the body can be made—it may be considered as the gyroscope of the head.

Semicircular Canals.—The mechanism for detecting movement of the head consists of three semicircular canals, situated in the three planes of space. They are filled with fluid—the endolymph. Each canal forms a circle which is completed in a common chamber—the utricular chamber—so that the endolymph may flow through each canal. Projecting into the lumen of each canal at a dilated area—the ampulla—is a tuft of nervous hair cells situated on a transverse ridge—the crista. Resting on top of these hair cells is a gelatinous mass—the cupula. Movement of the head in any given plane causes a relative movement of the fluid in the canal of that plane. In reality, it is rather a lagging of the fluid and cupula from inertia that stimulates the projecting hair cells so that a nerve impulse travels to the brain, which is interpreted by the animal as a movement of the head in a certain direction, and readjustments of the limbs and eyes are made accordingly. Each canal is maximally stimulated by a movement in one direction. There is a canal in the same plane in the opposite ear but turned in the opposite direction, which detects the reverse movement, so that, as pointed out by Crum Brown, the six canals are so arranged that for each of the three planes there is a canal in each ear, but oppositely directed—for example, the two horizontal canals are opposite to each other; the anterior vertical canal of one ear is opposite to the posterior vertical canal of the other ear.

The semicircular canals depend for their stimulation upon the movement of the head and the resultant inertia of the contained fluid and cupula. When there is no movement of the head, the fluid and cupula are at rest, so there is no stimulation of the hair cells, and, therefore, no information as to the position of the head forthcoming from the semicircular canals.

This theory of the flow of the endolymph in the canals is the one generally accepted as the basis for clinical examination

of the labyrinth. It is not accepted by all physiologists, but for our present purpose we will consider it as correct.

Otoliths.—The otolithic mechanism supplies the information as to the position of the head in space when the head is at rest. An otolith consists of a flat cup or disc of nervous epithelium with projecting hair cells—the macula—and resting on this is a membrane of greater specific gravity—the otolithic membrane. In some of the lower animals this membrane is filled with calcareous deposit, hence the name, ear-stone, or otolith. The stimulus to the macula is the pull or pressure of the superimposed otolithic membrane. For example, if the head is erect, the weight of the otolithic membrane is evenly distributed on the utricular macula, which lies in the horizontal plane. If the head is moved to one side the otolithic membrane is pulling more on one side than the other, and nerve impulses are set up in that part of the nervous epithelium, which are interpreted by the animal as a definite position of the head. It is a position or gravity phenomenon. This stimulation continues as long as the head maintains this position. Magnus regards the maximum stimulus as the pulling of the otolithic membrane on the macula, and this pulling causes an increase of tone in the extensor muscles of the limbs. Quix considers that pressure of the otolithic membrane on the macula is the maximum stimulus and that this causes an increase in tone of the flexor muscles of the limbs. However, for practical purposes these two theories are very similar. When the otolithic membrane is pulling, there is a maximum extension and a minimum flexion. When the otolithic membrane is pressing on the macula there is a maximum flexion and a minimum extension.

In the human ear there are two maculae—the utricular macula, which lies in the horizontal plane, and the sacular macula, which is more or less in the vertical plane. Each is in a separate chamber, but they are connected through the ductus endolymphaticus. The ductus ends subdurally in the saccus endolymphaticus. The saccular chamber, besides being connected to the utricule, is also connected to the cochlear duct by the ductus reuniens.

The Vestibular Nerve.—The nerves from the different parts of the labyrinth pass to the ganglion of Scarpa in the internal

auditory meatus. The fibers from these nuclei unite with the nerve from the cochlea to form the main body of the eighth nerve. The nerves from the saccule and posterior vertical ampulla unite to form one branch. The nerve from the utricule and from the horizontal and anterior vertical ampulla form the second branch of the vestibular nerve. At the medulla, the vestibular nerve separates from the cochlear branch and enters by a different route to join the vestibular nuclei:

1. The dorsal vestibular nucleus or principal nucleus.
2. Its ventral prolongation, the nucleus of the descending tract.
3. The lateral vestibular nucleus, or Deiter's nucleus.
4. The superior vestibular nucleus, or nucleus of Bechterew.

From these nuclei there are connections with:

1. The posterior or medial longitudinal bundle to:
   a. The external ocular nuclei. It is through these paths that impulses travel to produce nystagmus and compensatory eye positions and movements.
   b. To the vagus, impulses for nausea and vomiting, dyspnea, circulatory disturbances, etc., are carried through these paths.
2. The cerebellum to the nuclei Fastigii, emboliformis and globosus.
3. The cerebrum for sensations of vertigo, etc.
4. The cord. It is through these paths that impulses for changes of muscle tone and limb movements, etc., are carried.

The detailed intracranial terminations of the vestibular nerves are still little understood.

Magnus and DeKleijn have shown that in a thalamus animal —i. e., an animal from which the forebrain and corpora striata have been removed—all the vestibular reflexes are preserved. The muscle tone is normal. Such an animal can walk, run and jump. If it falls it can regain its normal position again. They have shown that when the cerebellum is removed all the labyrinthine reflexes are still present. Rodemaaker undertook to determine the most caudal transection that could be made through the mesencephalon and still preserve normal muscle tone and normal righting reflexes. He found that if the transection was made just oral to the level of the red nucleus that all these reflexes remained normal. If the region

of the red nucleus was damaged, decerebrate rigidity appeared. He also found that all centers for the various labyrinthine ocular reflexes lie caudal to the oral end of the level of the oculomotor nuclei. These ocular reactions persist after destruction of the corpora quadrigemina and Forels' decussation of the rubrospinal tract. Rodemaaker has since confirmed the fact that after the removal of the cerebellum in cats, dogs and monkeys, all the known vestibular reflexes are normal.

Jones and Fisher describe the pathways in the brain stem from the horizontal and vertical canals as different. Their view is based upon clinical investigation and interpretation of postmortem results. There are no physiologic experiments or histologic proofs to confirm this view. As yet the intracranial connections of the individual parts of the labyrinth, from each canal or from each otolith are unknown. The difficulty has probably been twofold:

Firstly, it is difficult to carry out ablation experiments on the individual parts of the labyrinth without injuring the remaining structures.

Secondly, the nerve fibers from the ampullæ and maculæ have a synapse in Scarpa's ganglion, so that degeneration of the nerve fibers, which would follow destruction of an ampulla or a macula, would probably not extend beyond this ganglion, which lies in the internal auditory meatus. The degeneration of the fibers from each ampulla or each macula does not extend into the brain stem and, therefore, cannot be traced by the usual methods.

Accurate work on these tracts will add greatly to our knowledge of the labyrinth and increase its diagnostic value in intracranial diseases.

PHYSIOLOGY OF THE SACCULAR MACULA.

From the anatomy just discussed, it will be seen that the saccule, being a part of the pars inferior of the labyrinth, is below the dividing membrane of de Burlet. The cochlea forms the remaining part of the pars inferior.

Anatomy of the Saccule.—The saccule is connected to the cochlea by the ductus reuniens, through which there is a free communication of the endolymph. The patency of this duct has been demonstrated by Guild's injection experiments. The

dye which he injected into the cochlear duct passed freely through the ductus reuniens into the saccular chamber on its way to the ductus endolymphaticus. The saccule is also connected to the utricule, which is in the pars superior of the labyrinth. The connection is through a small duct, which each gives off, called the ductus utriculosaccularis, which forms the ductus endolymphaticus.

Having already discussed the physiology of the cochlea, we must now consider the physiology of the saccule before leaving the discussion of the pars inferior of the labyrinth. On account of its association with the cochlea in the pars inferior the saccule has been considered by many as a part of the sound receiving mechanism. On the other hand, because of the similarity of its structure to the utricule in many animals and because of its topography, it has been considered as a part of the equilibrial apparatus. The saccule is present in fish, amphibia, birds and mammals. In the mammals the structure of the saccule is very similar to that of the utricule—that is, it consists of a cup or disc shaped membrane of highly specialized nervous epithelium, upon which rests a heavier membrane called the otolithic membrane. This upper, heavier membrane, pressing upon the underlying hair cells, is the stimulus which sets up the nerve impulse from the saccular macula. In the frog the structure of the saccule is very different from that of the utricule. There is the same underlying principle, but very much modified. McNally and Tait (1925) called attention to a very beautiful architectural arrangement, which is not present in the utricule.

Another point which might be mentioned with regard to the anatomy is that in the frog the chain of ossicles from the drum membrane actually ends in a window or aperture equivalent to the oval window in the human but which is actually an opening in the saccular chamber above and lateral to the level of the saccular macula. This may or may not be of some significance.

Function of the Saccule.—The Dutch school, arguing from the position or the topography of the macula, believed that it is concerned with certain compensatory eye positions and asymmetrical labyrinthine righting reflexes.

Compensatory Eye Positions.—Compensatory eye positions are reflexes, which were first described a century ago by Hunter and Von Graefe and others, but first classified as otolithic reflexes by Breuer. They result following head movements in such a way that the eyes change their position in the orbit in the opposite direction, the change of position of the head being partially compensated for. This reflex is more obvious in animals with laterally placed orbits. For example, if a rabbit's head is rotated to the right the eyes roll to the left —that is, the left eye goes down and the right eye up. This is accomplished by a cooperation of labyrinthine and neck reflexes. The vertical compensatory eye positions in the rabbit and the guinea pig and the rotatory compensatory eye positions in the monkey and man were ascribed to the saccule.

Righting Reflexes.—The righting reflexes are those by which an animal from every abnormal position in space is able to restore itself to normal position. There are five groups of reflexes cooperating in this, only one of labyrinthine origin. The labyrinthine righting reflexes act upon the head. If an intact animal is held by the pelvis in the air, the head is always brought into the normal position. If from a lateral position—that is, if the body has been bent over to one side or the other —it is an asymmetrical righting reflex. The asymmetrical righting reflexes were considered to arise from the saccule.

Removal of Otolithic Membranes.—The saccular macula lies in an almost vertical plane posterolaterally. It is, therefore, practically at right angles to the utricular macula. Using the method of Wittmaack, which is to centrifuge anesthetized guinea pigs at a high rate of speed, the Dutch school succeeded in throwing off the otolithic membranes from the utricular and saccular maculæ. To make sure of the exact lesion, all specimens were examined postmortem, histologically. The cristæ of the semicircular canals remained normal. When these animals were examined after the turning it was discovered that they had lost a number of equilibrial reflexes, namely, compensatory eye movements, labyrinthine righting reflexes, labyrinthine tonic effect on the limbs, etc. The reflexes which were absent in the centrifuged guinea pigs were, therefore, considered to arise from the two otolithic maculæ, the saccule and utricule of each ear. The difficulty was to

decide the reflexes belong to each macula. There were no isolated extirpation experiments on the individual parts of the labyrinth in the mammal up to this time.

Topographic Study.—Since all these absent reflexes were postural or static reflexes, it was decided to study the positions of the different maculæ to see if there was a characteristic position for either macula when a certain reflex was most marked. As mentioned before, it was from this topographic study that cetrain equilibrial reflexes were ascribed to the saccular macula, the remaining ones being considered utricular in origin. By this same method of reasoning, from the position or topography of the macula, Quix has evolved a very complex set of past-pointing tests, which he considers as diagnostic of saccular disease in man.

Ablation Experiments on Saccule.—Experimental stimulation and ablation of the saccule do not confirm these deductions. Laudenbach (1899) showed that washing away the saccular otolith in the frog, the remaining part of the labyrinth not being interfered with, caused no change in the equilibrial reactions of the animal. These results were confirmed by Parker in the dogfish and by Maxwell in the frog and dogfish. However, it was objected to this experimental work that what was true of the saccular macula in the fish and amphibia was not necessarily true in the mammal. This objection is quite justified, but the function of an organ in one of the lower animals often suggests what the function will be of the same organ in the mammal.

McNally and Tait (1925) sectioned the nerves to the saccular macula in the frog on one side and on both sides, but could demonstrate no change from the normal animal. The reactions to slow and fast tilting and to centrifugal force were quite normal. Such an animal jumps and swims normally. When the nerve to only one saccular macula is cut there is no asymmetry of movement or position.

Versteegh (1928) working in Magnus' Laboratory has finally succeeded in carrying out individual ablation experiments on the two otoliths in a mammal—the rabbit. Following destruction of the saccular otolith and macula in the rabbit, without injuring the structures in the pars superior, he has been unable to detect change in any of the known labyrinthine

reflexes. The asymmetrical righting reflexes of the head and the vertical compensatory eye movements and positions formerly ascribed to the saccular macula in the rabbit were still normally present in the operated animal. It may, therefore, be concluded that in the frog, the dogfish and the rabbit—a mammal—the removal of the saccular macula of one or both sides does not in any way interfere with the equilibrium or vestibular reflexes of the animal. There is, therefore, no experimental basis for the clinical tests at present suggested for the diagnosis of saccular disease. The complex past-pointing tests and the highly complicated methods of detecting compensatory eye positions in man have, therefore, no value in diagnosing saccular disease.

Saccule as Part of Sound Perceiving Mechanism.—Since the theory of the equilibrial function of the saccule has not been substantiated by experimental evidence, it might be worth while to consider the association of the saccule with the cochlea as part of the sound receiving mechanism. Parker (1909) studied the hearing reaction in fishes. He experimented with the fundulus and the dogfish. He found that the fundulus did not respond to a pure sound or noise, which was made above the water of the tank. To elicit a response the vibrating body had to be directly in contact with the walls of the tank in which the animal was swimming. He found that an electrically controlled tuning fork, the base of which was attached to a board at the end of the tank, gave the most satisfactory results. This elicited a definite response from the fundulus. When both labyrinths or both eighth nerves were sectioned the animal did not respond. On the other hand, when the lateral line nerves were severed and the skin of the head anesthetized the animal still responded normally to the sounding tuning fork. In this animal he was unable to carry out ablation experiments on the individual parts of the labyrinth. Similar experiments were then repeated by him on the dogfish. To elicit a response from the dogfish it required a louder, jarring noise. He used a swinging pendulum, the ball of which was allowed to strike the wall of the tank. To this the fish showed a definite response. When the eighth nerves were cut or both labyrinths destroyed the animal did not respond except to the very strongest stimulus, whereas, when the lateral line nerves

were cut and the skin about the head cocainized the animal still responded to the small stimulus required to elicit a response from a normal animal. Parker then succeeded in washing out the saccular otoliths on each side. The equilibrium of the animal was not disturbed, but when subjected to the sound vibrations the animal did not respond except to the strongest stimuli.

Hearing in Fishes.—From these experiments, Parker concluded that certain fish do hear and that in the dogfish the removal of the otoliths interferes with the hearing. In these experiments Parker takes into account that hearing in fishes must be considered apart from the effect of gross disturbance and vibrations that normally are perceived by the sense of touch. He, therefore, defines hearing in these animals as that sensory activity resulting from a stimulation of the ear by material vibrations. With this definition as a basis, he is justified in concluding that the dogfish hears and that after the removal of the saccular otolith the hearing is interfered with. Parker, therefore, considers as heard any vibration which is effectively detected by the ear.

Saccule as Vibration Receptor.—Prof. Tait and I, in considering the function of the saccular otolith, have attempted to modify Parker's experiments in order to dissociate the perception of sound vibrations of more than 16 per second, which are perceived by the cochlea—hearing as we ordinarily understand it—from the perception of a vibration of a frequency of less than 16 per second, and which we ordinarily refer to as a vibration. The sound transmitted to the dogfish in Parker's experiment, as he himself states, was certainly more in the nature of a fine vibration than of a sound, as we ordinarily understand it. Is it possible, therefore, that the saccule is the organ of reception for these low vibrations and that the cochlea, which only appears in a higher development of the animal, is the organ for the perception of pure sound as we know it, vibrations of more than 16 per second? If this were true, therefore, the cochlea is stimulated by a vibration of more than 16 per second. The saccule is stimulated by a vibration of less than 16 per second, down to the point where the vibration becomes so slow that it is almost translation when it is sensed by the semicircular canals. The saccular

otolith, therefore, would be intermediary between the cochlea on one hand and the semicircular canals on the other. According to this idea, Parker's experiments of the weight falling against the tank would be considered as a vibration affecting the saccule. According to Parker, the fish hears the sound, and, according to our idea, the fish senses the fine vibration with the saccular macula, a vibration which is not sufficiently gross to affect the lateral line or surface touch mechanism of the dogfish.

Experimental.—We examined normal and decerebrate frogs by placing them on a small platform, which could be vibrated at will. These frogs showed a very definite response, which consists of slight extension movements of the limbs and toes, etc. Finding this definite response was encouraging. The vibrator makes a very definite amount of noise. When the animal is placed immediately beside the vibrator, and yet not in contact with it, it is not in any way affected by the noise as such, so that the response mentioned above is a pure response to vibration and not a response to sound perception. Following section of both saccular nerves, however, in the frog, this response to vibration is still present, so that in the frog at least the saccular macula is not the sole receptor for vibrations.

These experiments with many modifications are still in progress, but so far we have been unable, in the frog, to ascribe to the saccular macula the seat of response to fine vibrations. So far our experiments, therefore, do not support nor do they contradict Parker's results in the dogfish.

From these remarks it will be seen that there is very little positive experimental work to ascribe a function to the saccular macula. Till its definite function is decided upon, clinical tests are of very little value and often misleading.

PHYSIOLOGY OF THE SACCUS ENDOLYMPHATICUS.

We have already mentioned that the pars inferior of the labyrinth is connected to the pars superior through the ductus utriculosaccularis, which is a direct connection between the saccule below and the utricule above. This utriculosaccular duct becomes the ductus endolymphaticus, which ends subdurally in the saccus endolymphaticus.

Anatomy of the Saccus Endolymphaticus.—The saccus lies on the posterior surface of the petrous bone. Its position is on the outer end of a horizontal line from the internal auditory meatus to the groove for the lateral sinus. The saccus actually overlies the lateral sinus in part. Owing to this intracranial subdural position of the saccus, much speculation has taken place as to its possible function. Many theories have been formulated regarding the possibility of its acting as a pressure transmitting mechanism from the brain to the labyrinth, and vice versa.

In spite of all that has been written about the saccus, very little experimental work has been carried out upon it. This is probably due to its relatively inaccessible position. Some of the most comprehensive recent textbooks on physiology do not mention the physiology of the saccus at all. However, since the saccus is being considered in the clinical journals, it may be timely to discuss its generally accepted physiology.

Experiments.—The experiments of Portmann (1921) are the first that can be found. He investigated the anatomy of the saccus in different species of animals, including man, and he carried out some experiments on the living animal. He chose a selacien, "Leiobatis Pastinaca." In this little fish, however, the endolymphatic canal ends in an endolymphatic recess called the porus endolymphaticus, which intead of being a closed sac actually opens on the surface of the head between the animal's eyes. It is not at all connected with the intracranial cavity. He cauterized the porus endolymphaticus and showed by subsequent histologic section that the duct was sealed by the cautery. The operated animals, when returned to the tank, showed marked disturbance of equilibrium. The disturbance, however, was not characteristic and varied in different animals. The onset and duration of the disturbance also varied widely. Portmann concluded that an intact endolymphatic mechanism is necessary for the normal functioning of the labyrinth.

The fact that in these animals the endolymphatic system opens on the surface of the body rather than in the intracranial cavity would throw some doubt upon the pressure transmitting theories of the saccus endolymphaticus between the brain and the labyrinth.

It has been shown by Magnus and deKleijn, that the well-known diminution of tonus of the homolateral limbs following unilateral labyrinthectomy partly depends upon a tonic neck reflex evoked by the turning of the head and partly upon a direct labyrinthine influence. The neck reflexes can be eliminated by correcting the turning of the head. The direct labyrinthine influence then becomes apparent, and lasts in different species of animals for a varying length of time, in rabbits, usually about two months. This labyrinthine influence, which up till now has not been brought in relation to any known reflex from the vestibular organ, does not, however, appear after paralysis of the labyrinth by injection of cocain into the middle ear of guinea pigs, which removes all other reflexes evoked from the vestibular organs.

Arndts, working in the same laboratory, has shown that the tonus diminution in the limb is also present after section of the eighth nerve on one side. He further showed that puncture of the round window membrane evoked the same difference of tone without any other symptoms or paralysis or stimulation of the vestibular organs.

In pursuing these investigations in Magnus' Laboratory, I was able to show by puncturing the round window membrane, without directly injuring the membranous labyrinth, that the tonus diminution appears as the result of the release of the perilymphatic fluid.

These facts led to the belief that the tonus diminution might be brought about by the influence of some outlying part of the labyrinth. For this reason, it was decided to investigate the saccus endolymphaticus to determine what part it played, if any, in the tonus diminution in the limbs.

A careful study was made of the saccus endolymphaticus in the rabbit. From a histologic serial section of the rabbit's labyrinth the saccus was exactly located in the intact temporal bone. It was found that in the living animal the saccus endolymphaticus could be reached through an opening made in the skull over the vermis of the cerebellum. We carried out three sets of experiments, namely, incising the saccus, applying continuous pressure over the saccus, and destroying the saccus endolymphaticus by cautery. There was no striking disturbance of equilibrium following any of these

experiments. In fact, immediately after operation all the known vestibular reflexes were perfectly normal. The animal showed no disturbance, whatever. In cases where the saccus was incised, about ten hours after operation, a very slight diminution of tonus occurred in the homolateral limbs and persisted for a varying period up to about two weeks. This late appearance of the homolateral diminution of tonus was in marked contrast to the tonus diminution which appeared immediately after the rupture of the round window membrane in our previous set of experiments. The late appearance of tonus diminution following incision of the saccus endolymphaticus would indicate that this phenomenon is not brought about by interference with a possible receptor organ situated in the saccus. This tonus diminution also appeared in the rabbit in which the saccus was cauterized, but without histologic section it is impossible to say whether the ductus endolymphaticus was open or whether, as in Portmann's cases, the duct was sealed. However, the absence of gross vestibular disturbance, and judging from the occurrence of the tonus diminution, which always occurred when the saccus was incised, it would seem that in this case the ductus endolymphaticus was not sealed. In the best case of continued application of pressure over the saccus endolymphaticus, and this pressure was kept up for a month, there was no disturbance whatever of any known labyrinthine reaction. This last experiment would cast doubt upon the theory that the saccus endolymphaticus transmits changes of intracranial pressure to the labyrinth which bring about labyrinthine disturbances.

We concluded from our experiments that the saccus endolymphaticus is not the seat of a receptor organ, which has control over the tonus of the limbs, and that after total ablation of the saccus endolymphaticus by the cautery, the labyrinthine reflexes were not interfered with (except for the late appearing slight change in the tonus of the homolateral limbs before mentioned).

Injection Experiments.—Guild (1927) carried out a series of injection experiments in the guinea pig's ear. His object was to determine the course of the flow, if any, of the endolymphatic fluid. He made an opening and counteropening into the ductus cochlearis—the membranous cochlear duct—through

the promontory and injected a small quantity of equal parts of potassium ferrocyanide and iron ammonium citrate in aqueous solution. The animals were then killed at intervals from 45 minutes to 45 hours after the injection. The temporal bones were then fixed and treated with acid so that the injected fluid was precipitated as prussian blue granules, and the bones were then cut in histologic serial sections. He found that the fluid was carried through the ductus reuniens into the saccule and then into the ductus endolymphaticus to the saccus endolymphaticus. He found, further, that in an area of the saccus wall of specialized epithelium—an area of increased vascularization, etc.—the granules were actually in the wall, so he concluded that they were being absorbed into the circulation through this specialized area, to which he has given the name "pars intermedia." To quote his own conclusions: "The endolymph is formed by the striae vascularis, flows towards the basal end of the cochlear duct and through the canalis reuniens into the sacculus and from this through the ductus endolymphaticus into the saccus endolymphaticus and leaves the membranous labyrinth by passing through the wall of the pars intermedia of the saccus into the numerous small blood vessels of this region."

As was pointed out before, this region just overlies the lateral sinus. Guild believes that the saccus endolymphaticus serves as the principal place of outflow of the endolymph.

When considering Portmann's and my results in the light of Guild's work, it will be seen that when Portmann sealed the ductus endolymphaticus in the fish, he probably brought about a condition of increased intralabyrinthine pressure, which may have caused the equilibrial disturbance described. On the other hand, the results in my experiments would seem to indicate that I hastened the flow of the endolymph in the experiments where I incised the saccus, and did not interfere with the endolymphatic flow at all when I simply applied pressure with a rubber clamp. There was no equilibrial disturbance, therefore, in my animals.

Clinical Significance of Saccus Endolymphaticus.—From these experiments it will be seen that it would be impossible to diagnose a localized lesion of the saccus endolymphaticus because the symptoms, if any, would be those of the associated

general labyrinthine disease. Such conditions, which are frequently reported in the literature of empyema of the saccus endolymphaticus, are always the result of general labyrinthine suppuration. The extension of the pus to the endolymphatic sac would be a means of setting up meningitis. The other common pathway of posterior fossa meningitis of labyrinthine origin is through the internal auditory meatus. As is pointed out by Eagleton, the tract of infection from the labyrinth can only be diagnosed by actually exposing the endolymphatic sac when opening the posterior fossa for meningitis. The majority of cases, however, of empyema of the saccus endolymphaticus are discovered postmortem.

Portmann has recently described an operation upon the saccus endolymphaticus to relieve a condition which he describes as labyrinthine hypertension. In discussing the indications for the operation, he admits that there is no definite test of labyrinthine hypertension. He believes that it probably exists in the course of general hypertension or a hyperexcitable sympathetic system. Though the indications are not specific, it would seem that the operation was indicated in any severe case of vertigo, tinnitus and deafness, the so-called Ménièrè's triad, which had resisted all forms of medical treatment. The incision of the saccus endolymphaticus is made by an approach through the mastoid region. He is unable to say how long the incision remains open, but he reports improvement in some cases over a period of two years.

Judging from my experimental results, this operation would only produce a temporary opening in the saccus endolymphaticus because the wound in my animals healed in about two weeks' time. In the human the cause of the increased intralabyrinthine pressure has not necessarily been affected or removed by the operation so that it is difficult to understand how this operation is more than a temporary measure for a condition which cannot be accurately diagnosed.

SUMMARY.

There is no experimental evidence to show that the saccular macula has any vestibular or equilibrial function, either in the mammal or in the lower forms of animals.

There is some experimental evidence to show that in the fish the saccular macula may be concerned with hearing.

Experiments on the saccus endolymphaticus would seem to show that it is not the seat of an end organ concerned with equilibrium or that it serves as a mechanism for transmitting changes of pressure from the brain to the labyrinth.

There is experimental evidence to show that the saccus endolymphaticus is the absorptive chamber for the endolymphatic fluid.

Part of the saccus wall is so modified in structure that it would serve as an absorptive area.

(To be concluded in the March issue)

Editorial

THE AMERICAN BOARD OF OTOLARYNGOLOGY.

Until the end of the great war there was no standardized preparation for the practice of otolaryngology. The student desiring to perfect himself in the practice of this specialty was at a loss where to seek information as to how and where he might secure the desired education.

When he sought advice from the various practitioners of otolaryngology it often happened that he received many different opinions.

As the result certain inequalities and inadequacies in the preparation of otolaryngologists developed.

Hospital boards, committees on admission to the various individual societies as well as members of the medical profession and the laity did not know what constituted a proper preparation for this work.

Recognizing this situation the various otolaryngological societies of America appointed The American Board of Otolaryngology. While this board apparently had as its object to examine into the fitness to practice otolaryngology of the persons whom it certified, as a matter of fact had as its main function the standardization of the preparation for the practice of otolaryngology.

It has been a potent factor in the preparation of curricula in our very best graduate schools and in the organization of the work of interns in otolaryngology.

It has stressed pathology, internal medicine, and pediatrics to the great benefit of the profession.

The importance to the laity of this standardization is evidenced by the fact that 60 per cent of all human ills are located above the diaphragm and that the otolaryngologist does give to the internist and to the pediatrician more useful information than any other specialist.

By comparing the practice of otolaryngology today with what it was ten years ago before the creation of the Board of Otolaryngology we must conclude that the board has more

than justified its creation. It has been the main factor in bringing about this change, which is so beneficial to both the laity and to the profession.

The young man or the young woman today knows just where to go and what must be done to become an otolaryngologist. They can easily ascertain where the approved residencies are. They know that they must have a certain proficiency before they can be certified. They do work hard to prepare for their examinations. They feel after they have passed these examinations that they have done something really worth while.

Committees on admission to the various special societies do not find it necessary to concern themselves regarding the fundamental preparation of their candidates. If they have been certified by the Board this requirement has been met.

Governing boards of hospitals know that persons who have passed the Board examination have the necessary qualifications to become members of their otolaryngological staffs.

Lastly, and perhaps the most important, the laity knows that individuals who are certified have special qualifications for the practice of otolaryngology.

Much credit should be given to The American Board of Otolaryngology for what it has accomplished. Much credit must be given to the various special societies and to the members of the otological and laryngological professions for the help which they have given to the Board. Without the constructive help of these two groups the efforts of the Board would have been of no avail.

XCIV.

DEDICATION OF CENTRAL INSTITUTE FOR THE DEAF.

By L. W. Dean, M. D.,

St. Louis.

On June 19, 1929, the Central Institute for the Deaf was dedicated at St. Louis. Attending the exercises were representatives of all the leading otologic societies and the societies interested in the care of the deaf child. The representatives were there to honor Dr. Max A. Goldstein, the founder and director of the Institute.

The reception given to Dr. Goldstein was a wonderful demonstration of the spirit in which his scientific and his unselfish work for the deaf child have been received by the scientific world at large and by the people of St. Louis.

Educational institutions and learned societies sent the following representatives to assist in honoring Dr. Goldstein at the dedication: Dr. L. W. Dean of the Council, American Otological Society, director of otolaryngology at Washington University; Dr. George M. Coates of Philadelphia, secretary, American Laryngological Association; Dr. Robert Sonnenschein of Chicago, vice president, American Laryngological, Rhinological and Otological Society; Dr. Max F. Meyer, president, Midwestern Psychological Association and Southern Society for Philosophy and Psychology; Dr. G. Oscar Russell of Columbus, O., member of the conference, National Research Council, Conference on the Deaf; Miss Gertrude Van Adestine of Detroit, vice president, Society of Progressive Oral Advocates; Dr. Elmer L. Kenyon of Chicago, president, American Society for the Study of Disorders of Speech; Dr. H. McKim Marriott, dean, Washington University Medical School.

The Central Institute for the Deaf is located at 818 South Kingshighway, St. Louis. The buildings, fronting Forest Park and extending between Clayton avenue and Papin street, cost over $400,000, including equipment and the site. It is joined with the older and smaller home of the institute, which had

set back some distance from Kingshighway. This is the latest augmentation of St. Louis' internationally known medical center. Central Institute is known throughout this country and abroad for its work in aiding the deaf through progressive oral methods, its Training School for Teachers and its Department of Corrective Speech, and the enlarged plant will permit a notable extension of its work.

Dr. Goldstein with the cooperation of the teachers in the school has completed the following original investigations: Creation of the acoustic method of instruction, whereby the hearing mechanism is stimulated to its greatest usefulness, with special attention to residual hearing of the partially deaf.

Establishment of the first two-year training school for teachers of the deaf with a university curriculum and entrance qualifications; more than 500 graduates.

Organization of the Society of Progressive Advocates, a national teachers' body, upholding oral instruction as opposed to sign language, which opened its twelfth annual meeting here in St. Louis at the time of the dedication.

The society first introduced the audiometer to teachers of the deaf.

Introduction of the Osiso to the educational and medical professions. In connection with this an exclusive research is continuing, with a textbook on the graphs of speech under way.

Demonstration of the possibility of analysis of speech by deaf children through the tactile sense, with simple apparatus.

Personal research in translation and substitution of sense-organs by the director.

Central Institute was the first graded school for the deaf to accept pupils of kindergarten age. It raised the work of correcting speech defects to a science. In connection with this latter work it maintains a free clinic for the diagnosis and correction of speech defects in Washington University Medical School.

The new Institute building is of modified Spanish exterior design with walls of buff brick trimmed in terra cotta. It is four stories high. As one goes through the building he is impressed by the forethought for children. Next to the dor-

mitory is a small isolation ward. On the roof is an outdoor covered gymnasium 40 by 110 feet.

In the building are specially constructed dormitories and classrooms, quarters for pre-school age deaf children. There are soundproof laboratories for the routine examinations and research. There is a phonetic laboratory for the Osiso work.

Then there is the Grove Memorial Library which contains a very extensive collection of books dealing with the deaf and defects in speech. Many of the books in the library have been collected by Dr. Goldstein from all over the world. It includes his private library. The library is available to all interested in the work.

Abstracts of Current Articles

Treatment of Labyrinthitis of Tympanic Origin. (Beitrag zur kenntnis der behandlung der tympanzgenen labyrinthiten.)

F. W. Törne (Lund, Sweden), Acta. Oto-Laryng., Suppl. IX, 1929.

Consideration of the literature and of his own twenty-four cases, of which thirteen lived and eleven died, leads the author to the following conclusions:

In circumscribed labyrinthitis, lumbar puncture should be done frequently, and meningeal changes will frequently be detected. If a middle ear operation be done for other reasons in such cases, there is distinct danger of lighting up the labyrinth. Cases without cholesteatoma are more dangerous than those where cholesteatoma is present. He has had several satisfactory results from labyrinthectomy in such cases.

Similarly the spinal fluid should be closely watched where symptoms of serous labyrinthitis are present, especially when great reduction of cochlear and vestibular function has occurred. Simple operation is not advisable; he agrees with the general view that great loss of function should indicate the radical operation and labyrinthectomy at one sitting.

In acute purulent labyrinthitis he advises immediate labyrinthectomy, pointing out that the radical operation alone might readily in such a case spread the infection to the meninges. Changes in the spinal fluid are a positive indication, but negative findings do not correspondingly permit of delaying the labyrinthectomy, either in acute or latent purulent involvement. Since one-fourth to one-third of untreated cases die, operative treatment is obviously indicated, and Törne was able to save thirteen out of fourteen cases where changes in the spinal fluid had not taken place. F.

Vertigo of Hypertension. (Le vertige des hypertendus.)

V. Lassance (Bains-les-Bains), Vie Médicale, 10:469, May, 1929.

Passing states of congestion or anemia of the labyrinth may lead to functional irritability in which the entire vagosympathetic mechanism may participate; finally gross vascular

changes ensue, with sclerotic or hemorrhagic pathology. Presence of wax or foreign bodies in the canal is much more irritating to these patients. Reflux of blood after temporary anemia, comparable to the formication of a limb wherein the circulation has been temporarily arrested, will not only cause tinnitus but also vertiginous symptoms, often of severe degree. Repetition of these symptoms, often accompanied by nausea, drives such persons into a state of apprehensive invalidism. The danger of accidents to the intracerebral vessels is clearly pointed out by such seizures, and active collaboration between the internist and otologist is required. F.

Suboccipital Cistern Puncture in the Complications of Suppurative Otitis Media. (La ponction occipito-atloidienne dans les complications de l'otite moyenne suppurée.)

A. Gaston (Paris), Arch. Int. Lar., 8:385, May, 1929.

Working under Prof. Lemaître, the author advises that in the presence of serious complications, negative lumbar puncture should be followed by suboccipital cistern puncture. Discovery of organisms in the smear and on culture from the centrifuged fluid is much more likely. Deceptive feelings of security, resulting in deferring radical surgical procedure, may be based on apparently negative lumbar findings. In certain cases of meningitis, fibrinous exudates will prevent the extension of cytologic or chemical changes indicating bacterial invasion of the lumbar region, until the terminal stage. Acute labyrinthitis arising during an acute otitis media should suggest cistern puncture. Recovery of the infecting organism in this manner is of great prognostic value. Gaston and Lemaître agree with Knick, Ramadier, Uffenorde and Kindler that cistern puncture is without danger to the medulla and may be done daily if necessary. Using the spinal manometer, they consider the sign of Quekenstedt (failure to increase pressure of cerebrospinal fluid on compression of thrombosed jugular) much easier to demonstrate. F.

A New Aid for the Deafened. (Un nouvel appareil acoustique.)

F. Ferrière (Geneva), Arch. Int. Lar., 8:442, May, 1929.

The author has designed a portable two-stage radio amplifier, with batteries, which may be carried to public meetings, the theater, etc., making use of a head set mounted in sponge

rubber to avoid mechanical vibrations. Also he has devised a method of adapting the head-set microphone to bone conduction, by affixing a concave ivory button to the microphone armature. This ivory button is held against an upper incisor, the microphone being held in the palm, concealed by a handkerchief. Similarly a bone cigarette holder may be gripped in the teeth, and the microphone placed in contact with its outer end; or the microphone may rest on the knees and a vulcanite rod held by the teeth may be use for the contact. F.

The Citelli Method for Diagnosis and Cure of Frontal Sinusitis. (Il metodo Citelli per la diagnosie cura delle sinusiti frontali.)

C. Raimondo (Reggio Emilia), Arch. Ital. O. R. L., 40:211, Apr., 1929.

Citelli has since 1917 entered the frontal sinus through a skin-periosteal incision 1 cm. long at the inner angle of the orbit, making a 3 mm. bone opening with Collin's hand perforator. Irrigation once or twice daily with saline or boric solution, rarely a few drops of other antiseptics, and keeping the wound open with a little gauze wick, comprise the after-treatment. Raimondo cites nine cases entirely cured by this method. Preliminary radiographs are essential, and obstructing middle turbinates, or chronic ethmoiditis, must be done away with simultaneously. The nasofrontal duct is not interfered with, and its swollen mucosa becomes patent without local applications. Two acute exacerbations and two chronic cases were longest in healing—over sixty days. Most of the cases got well in thirty to forty days. Scarring was negligible.

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